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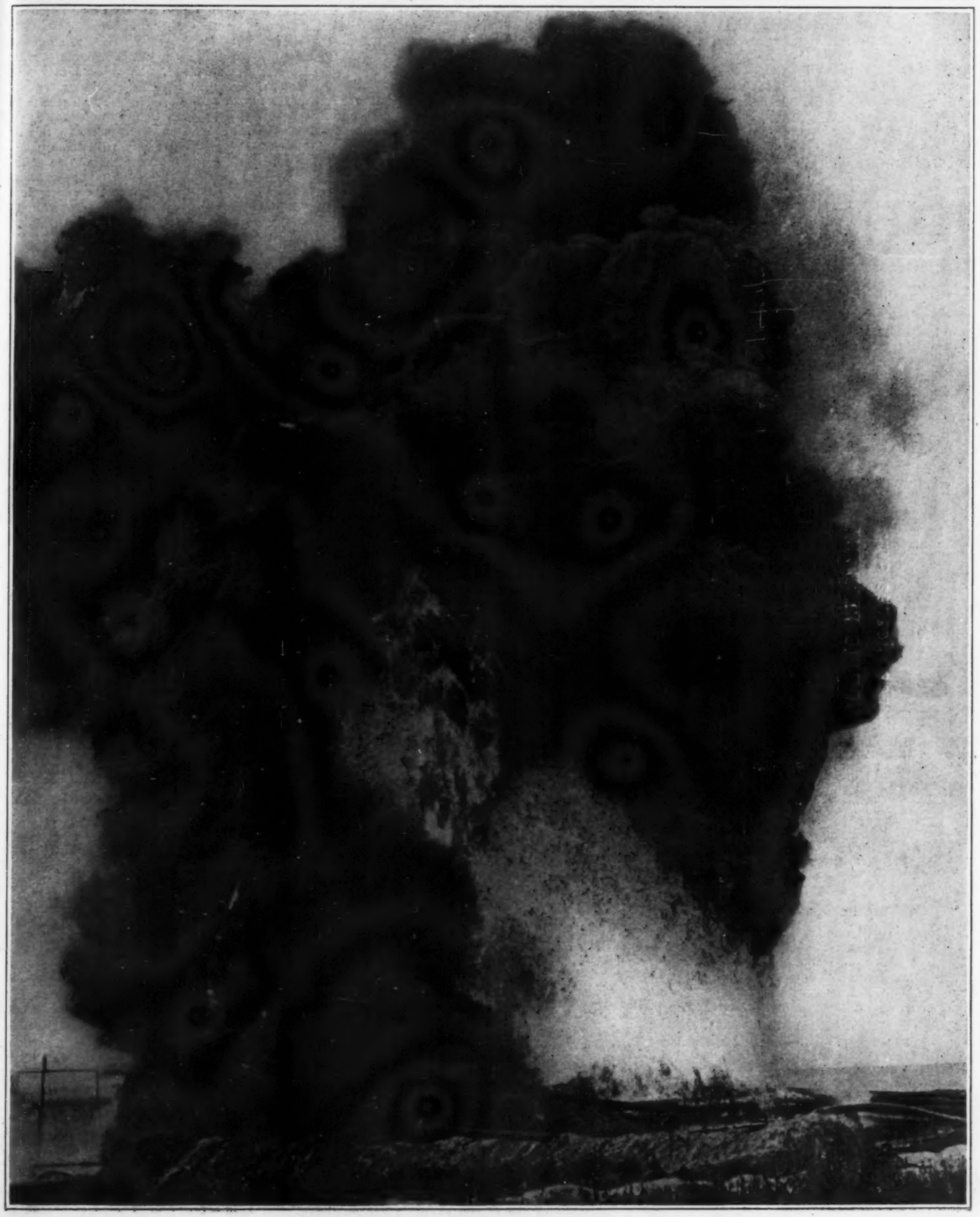


The "Golden Cycle" Gusher on Fire

THE ROTARY METHOD OF WELL DRILLING—(see page 248)

Epidemiology and Recent Epidemics*

Suppressing Epidemics by Fighting the Disease at its Source

By Simon Flexner, M. D.

Since the last congress, held in 1916 in the midst of the racking uncertainties of the great war, notable events and serious calamities have befallen the world and arrested the attention of all thoughtful men. A bitter and passionate military contest has been brought to a hopeful conclusion; but because of the unparalleled cost of the struggle, in lives and in treasure, deep unrest, revolution even, starvation and disease are prevailing over a large part of Europe, while also within the three-year period elapsed between the last congress and the present one three destructive epidemics of disease have ravaged the United States and the world.

Hence it has seemed fitting to me that on this occasion and before this representative body of medical men we should pause for a brief period in order to review, as it were, our knowledge of epidemics and at the same time of the practical hygienic measures, based on this knowledge, which we have already put or in ordinary course of events may reasonably hope to put into motion against the spread of these epidemics, so that we may form a judgment of the efficacy of such measures and arrive possibly at new points of view from which to launch a more decisive attack. Moreover, it seems imperative that we should consider not only the sum of our knowledge of epidemics, but also certain facts relating to the populations affected which react powerfully on the successful application of the hygienic means available.

Three epidemic diseases—poliomyelitis, streptococcus pneumonia and influenza—have been especially destructive in the western world during the past three years; also, because of certain common characteristics, they are well adapted for the purpose I have in view.

POLIOMYELITIS

In the United States we are becoming increasingly familiar with epidemics of poliomyelitis. Prior to 1907, infantile paralysis was a rare disease in this country; since then it has prevailed fitfully every summer and autumn, and in one notable instance, at least, in the winter season,[1] claiming victims by the score or hundred, until in 1916 an outbreak of unprecedented severity, with its center of violence in New York State, swept over a considerable number of states.

Fundamental knowledge of poliomyelitis may be said to have grown rapidly since Wickman's epochal clinical studies published in 1907. We are, indeed, today in possession of precise information covering essential data with regard to the nature of the inciting micro-organism, notwithstanding its very minute size, and also concerning the manner in which it leaves the infected or contaminated body within the secretions of the nasopharynx chiefly and gains access to another human being by means of the corresponding mucous membranes and apparently in no other way. Moreover, the inciting virus so called, up to the present time and notwithstanding many and assiduous efforts, has not been detected apart from the infected or merely contaminated human being, and there is therefore no foundation in ascertained fact for an assumption that the virus is conveyed to persons otherwise than by other persons who harbor it.

STREPTOCOCCUS PNEUMONIA

The second example, namely, that of streptococcus pneumonia, presents a phenomenon almost, if not quite, new among the epidemic diseases. It appears as if during the winter of 1917-1918 there occurred in several localities within the United States, and also, but in less degree, in France, at least a great increase in the incidence of a type of pneumonia which previously had been very infrequent. It appears also that the greatest number of cases and of fatalities arose in the United States in the military cantonments; that the disease first prevailed as a secondary pneumonia following measles; but that before long the severity of the infection was such that cases of primary streptococcus pneumonia began to arise. Moreover, at this juncture the disease spread from the military to the civil populations.

The nature of the micro-organism inducing this form of epidemic pneumonia is indicated in the name which the disease has come to bear. The difficulty in this instance has not been in finding out the inciting microbe, but rather in differentiating the streptococci responsible for the epidemic disease from streptococci possessing the ordinary pathogenic properties, or even from those of saprophytic nature so commonly present on the upper respiratory mucous membranes without provoking widespread disease. However, numerous studies of the bacteriology of this epidemic of pneumonia, at distinct and often widely remote cantonments, showed that the microbic incitant was in almost every instance *Streptococcus hemolyticus*. Moreover, because of the wide occurrence of the epidemic pneumonia, this type of streptococcus could be found in normal throats and as a secondary invading micro-organism in the lungs in cases of ordinary lobar pneumonia. Thus far very little progress has been made in the classification of streptococci, which form a class apparently even more heterogeneous than the pneumococci.

The point I wish to emphasize is this: Regarding epidemic diseases in general we are wont to assume the introduction from without, and usually from a distant locality, of a special kind of race of micro-organism which is held directly responsible for the epidemic ensuing. In the instance of the epidemic pneumonia, no such importation or new introduction of the inciting streptococcus needs to be or actually is assumed. It is so probable as to amount to practical certainty that the excessively virulent *Streptococcus hemolyticus* was developed by a process of selection, through successive transfer from person to person, and by gradual enhancement of its invasive properties.

We are in this case on safe grounds when we assert that the inciting streptococcus is always personally borne: that is, that it leaves the respiratory organs of one person to be introduced on the corresponding organs of other persons, and in no other manner. In other words, the mechanism or mode of infection in epidemic streptococcus pneumonia, as in poliomyelitis, may be said to be clearly apprehended.

INFLUENZA

The case of influenza, the third and perhaps the most important example cited, is quite different, since wide divergences of belief and opinion regarding the nature of the inciting micro-organism and the manner of infection still prevail. The reasons for these differences are several, but the most important, perhaps, relates to the common observation of the manner of spread or attack of the disease. To the casual observer there is something uncanny in the way influenza strikes down its victims. While other epidemics proceed from bad to worse, with at least progressive increases of intensity, influenza seems to overwhelm communities over even wide stretches of territory as by a single, stupendous blow. While in the one case the gradually accelerating rate of speed of extension may be taken to indicate personal conveyance of the provoking micro-organism, in the other the sudden wide onset appears the very negation of personal communication.

Hence the invoking of mysterious influences, the revival of the notion of miasm and similar agencies, to account for this phenomenon. Indeed, the public mind in general lends itself readily to such formless concepts, for the reason that there still resides in the mass of the people, even in the more enlightened countries, a large uneradicated residue of superstition regarding disease. One does not need to look far or dig deep in order to uncover the source of this superstition. We have only recently emerged from a past in which knowledge of the origin of disease was scant, and such views as were commonly held and exploited were mostly fallacious. It is, indeed, very recently, if the transformation can be said to be perfect even now, that the medical profession as a whole has been completely emancipated. All this is very far from being a matter of remote importance only, since in the end the successful imposition of sanitary regulations involves wide co-operation; and until the majority of individuals composing a community is brought to a fair level of understanding of and belief in the measures proposed, serious and sustained endeavor to enforce them is scarcely to be expected.

And yet no better instance of a communicable disease could perhaps be invoked than influenza to exercise the false idea of the mysterious origin of epidemics. To dwell solely on the sudden and overwhelming stroke of the disease is wholly to overlook the significant incidents that precede the mass infection, because they are of such ordinary nature and lack all dramatic quality. Accurate observers noted long ago that influenza in its epidemic form did not constitute an exception to the common rule governing epidemic diseases, which were obviously associated with persons and their migrations. What the early students made out by tracing the epidemic backward to its point of departure, more modern observers have confirmed by carefully kept records, often graphically compiled, as in the excellent instance of the Munich records covering the epidemic of 1889-1892, which can now be supplemented by a number of similarly constructed records of the epidemic just passed. These detailed records show convincingly a period of invasion during which there is a gradual rise in the number of cases, to culminate, within a period variously estimated at from one to three weeks, in a widespread, so-called "explosive" outbreak of the disease.

It happens that the early cases of epidemic influenza tend not to be severe, chiefly because they rarely are attended by pneumonia and hence are frequently mistaken, and the confusion in diagnosis is resolved only when the full intensity of the epidemic is realized. In the meantime, rich opportunity has been afforded for the free and unrestricted commingling of the sick and the well, of doubtless healthy carriers of the inciting agent and others, until so high a degree of dissemination of the provoking micro-organism has been secured as to expose the entire susceptible element of the population, which happens to be large, to an almost simultaneous response to the effects of the infecting microbe.

Deductions of like import can be drawn from the geographic movements of influenza epidemics. In eastern Russia and Turkestan, influenza spreads with the pace of a caravan, in Europe and America with the speed of an express train, and in the world at large with the rapidity of an ocean liner; and if one project forward the outcome of the means of intercommunication of the near future, we may predict that the next pandemic, should one arise, will extend with the swiftness of the airship. Moreover, not only is this rate of spread determined by the nature of the transportation facilities of the region or the era, but towns and villages, mainland and island, are invaded early or late or preserved entirely from attack according as they lie within or without the avenues of approach or are protected by inaccessibility, as in instances of remote mountain settlements and of islands distant from the ocean lanes or frozen in during winter periods.

It is desirable, in the interest of clear thinking, to carry this consideration of the characteristics of epidemic influenza a step farther. A feature of the epidemic disease of particular significance is the tendency to recur, that is, to return to a stricken region after an interval, usually of months, of relative quiescence. Thus the beginnings of the last pandemic

*President's address, read before the Tenth Congress of American Physicians and Surgeons, Atlantic City, N. J.

TO OUR SUBSCRIBERS

As explained in our last issue, that of October 11, publication of the SCIENTIFIC AMERICAN SUPPLEMENT *has been seriously hampered by the strike of compositors and pressmen, but despite all handicaps we are endeavoring to continue issuing this journal. In order to catch up with our schedule we published a double number last week combining the issues of October 4 and 11, and we are doing the same this week, combining the issues of October 18 and 25. We hope soon to resume our normal schedule, but in the meantime we beg your indulgence. We are doing everything in our power to serve your interests.*

in western Europe and the United States have been traced to sporadic cases appearing in April, May and June, possibly even earlier in certain places, while the destructive epidemic raged during September, October and November of 1918. There are very good reasons for believing that in itself influenza is not a serious disease, but that its sinister character is given by the remarkable frequency with which it is followed, under particular circumstances, by a concomitant or secondary pneumonic infection to which the severe effects and high mortality are traceable. Now it is this high incidence of pneumonia, the product of invasion of the respiratory organs with bacteria commonly present on the upper respiratory mucous membranes—streptococci, pneumococci, staphylococci, Pfeiffer's bacilli, and even meningococci—that stamps the recurrent waves of the epidemic with its bad name.

If we compare the pneumonic complications of influenza with those which arose in the cantonments in 1917-1918, first as attendants of measles and later as an independent infection, we note immediately that in both instances the severe effects and high fatalities arose, not from bacteria brought or imposed from without, but from their representatives which are commonly resident on the membranes of the nose and throat in health. Whatever we may have to learn of the micro-organism inducing measles, still undiscovered, and of influenza, still under dispute, and their mode of invasion of the body, no one would question that the bacteria inducing pneumonia are personally borne.

EFFICACY OF PUBLIC HEALTH MEASURES

With these various considerations before us, we may now discuss the question of the efficiency of our public health measures in diminishing the incidence of epidemic diseases. It should now be evident that our three examples are essentially instances of respiratory infections, that is, diseases in which the inciting micro-organism enters the body by way of the air passages, although not necessarily, as in poliomyelitis, directly injuring those parts. Protection in diseases of this class is not to be secured by applying sanitary measures on a wide scale to an extraneous and inanimate source of the infectious micro-organisms, as to water supplies contaminated with the dejecta of typhoid patients, or even to inferior species, such as the mosquito or the rat, which act as intermediaries in conveying the germs of yellow fever or of infectious jaundice; but it is alone to be attained by methods of personal hygiene, applied on the individual scale of safeguarding one person from another, the most difficult of all hygienic regulations to enforce.

Returning now to epidemic poliomyelitis, we may fairly claim that we are in possession of the essential facts which, if widely applicable, should enable us to control the spread of that disease. But we can, I think, hardly claim that up to the present time our accomplishments in that direction have been remarkable. It is sufficient merely to compare the curve of incidence of the Swedish epidemic of 1905, before the nature and mode of infection of poliomyelitis were known, with those of the last several years, in Massachusetts and New York State for example, in order to conclude that the progress of the epidemics in the several places was practically identical.

And, indeed, this is what might be expected in view of the difficulties surrounding the prompt and accurate diagnosis of poliomyelitis in its atypical and abortive, often ambulant forms. Once the disease is introduced under conditions favoring its epidemic spread, a wide dissemination of the inciting micro-organism takes place, and a constantly increasing number of persons becomes exposed to its presence before any restrictive measures are put into effect, and indeed also after they have been applied. In the case of poliomyelitis, as in that of influenza itself, a wide distribution of the infectious agent precedes the enforcement of preventive sanitary regulations. These considerations do not, of course, warrant intermission of the protective measures now in use, which undoubtedly save many individuals from exposure and thus from potential attack; they do, however, offer an explanation of why, up to the present time, greater success has not attended efforts at control once the epidemic is under full way.

The case with the epidemic pneumonias is of another order: They represent theoretically two diseases which should respond to methods of control based on our knowledge of their mode of infection. In the epidemic streptococcus pneumonia and the pneumonia following influenza we are dealing with pathologic conditions in which not a newly introduced, extraneous micro-organism is operating widely and insidiously, but one in which the active microbes concerned are examples merely of intensified races of common and almost omnipresent species belonging to the flora of the nasopharynx. The infectious agents in these instances are contained within the nasal, buccal and bronchial secretions, and are disseminated in the sprayed material which is coughed or otherwise thrown into the surroundings of the patients. The lesson, therefore, to be derived from the severe experience of the recent pneumonia epidemics is to the effect that measles and influenza patients are not to be assembled into large groups or kept in open wards, but should be placed in separate rooms or cubicles, where they and their attendants may be preserved as far as possible from sputum droplet contamination. In the instance of epidemic pneumonia, a chain of direct infection from one patient to another tends to be established, and hence the sanitary control of those diseases is to be sought through the breaking, as it were, of this vicious circle.

A distinction has now been intimated in the possibilities of direct sanitary control between the two epidemic diseases—namely, poliomyelitis and influenza—introduced from without, and the pneumonias, which are mere, if intense, exaggerations of sporadic diseases ordinarily prevailing. I propose now to lay before you a suggestion as to means of attacking the exotic epidemic diseases which may come to merit serious attention.

ERADICATION OF DISEASES IN ENDEMIC FOCI

Epidemic diseases in the commonly accepted sense have fixed locations—the so-called endemic homes of the diseases. In those homes they survive without usually attracting special attention often over long periods of time. But from time to time, and for reasons not entirely clear, these dormant foci of the epidemics take on an unwonted activity, the evidence of which is the more frequent appearance of cases of the particular disease among the native population, and sooner or later an extension of the disease beyond its endemic confines. Thus there are excellent reasons for believing that an endemic focus of poliomyelitis has been established in northwestern Europe from which the recent epidemic waves have emanated.

Similarly, there are excellent reasons for regarding the endemic home of influenza to be eastern Europe, and in particular the border region between Russia and Turkestan. Many recorded epidemic have been shown more or less clearly to emanate from that area, while the epidemics of recent history have been traced there with a high degree of conclusiveness. From this eastern home, at intervals usually of two or three decades, a migrating epidemic influenza begins, moving eastward and westward, with the greater velocity in the latter direction.

Now since the combating of these two epidemic diseases, when they become widely and severely pandemic, is attended with such very great difficulty and is of such dubious success, and this notwithstanding the prodigious public health contests which are waged against them in which the advantages are all in favor of the invading micro-organismal hosts, it would seem as if an effort of central rather than peripheral control might be worth discussion. According to this proposal, an effort at control amounting even to eventual eradication of the diseases in the regions of their endemic survival would be undertaken, an effort, indeed, not occasional and intensively spasmodic, as during the pandemic excursions, but continuous over relatively long periods, in the hope that the seed beds, as it were, of the diseases might be destroyed.

That such an effort at the eradication of a serious epidemic disease may be carried through successfully, the experience with yellow fever abundantly proves. In attacking that disease, the combat was not put off until its epidemic spread had begun and until new territory, such as New Orleans, Jacksonville and Memphis, had been invaded; but the attack was made on its sources at Havana, Panama and now Guayaquil, to which endemic points the extension into new and neutral territory had been traced.

I do not disregard the essential fact, in bringing this suggestion forward, that the control at its sources of yellow fever is quite another and probably far simpler problem than the control in their endemic foci of poliomyelitis and influenza. It is, perhaps, unnecessary to go far into the reasons why the latter would doubtless prove to be far more difficult of accomplishment than has been the former. I am not now engaged in presenting a plan of operation or proposing that the attempt at eradication be made immediately. Our knowledge of all the facts involved in the epidemiology of poliomyelitis, and especially of influenza, may still be too imperfect for immediately effective action. But the very magnitude of the problem of these otherwise uncontrolable epidemic diseases invites to an imaginative outlook which, while perhaps non-realizable today, may not, in view of the rapidly advancing knowledge of the infectious diseases, be hopelessly out of reach tomorrow.

Nor am I insensible to the labor and cost in money and talent which the setting out on such an ambitious enterprise would entail. But here, at least, is a world problem of such proportions and nature as to invite the participation of all the scientifically advanced countries in a common effort to suppress one of the most menacing enemies of civilized man and of human progress.

In proposing to strive for the high achievement, not merely of parrying the blows struck by destructive epidemics, but of rendering them impotent to strike in the future, we may pause for a moment to reflect on the different ways in which peoples react to great calamities, such as those brought by war and by disease. As the results of a cruel and devastating war, revolutions in governments supposed the most stable may occur; no such result follows on still more devastating epidemics. The recent epidemic of influenza claimed, possibly, more victims than did the great war, and the losses to the world in emotion spent, treasure consumed, and progress impeded are incalculable; yet, through a fortuitous circumstance of psychology, from the one calamity the world may emerge chastened, perhaps even bettered, while from the other, because of a depth of ignorance amounting often even to fatalism, mankind may largely miss the deep meaning of the lesson.

The Application of Heat to the Abdomen.

An old standby among our therapeutic measures is the application of heat to the abdomen. No matter what the pain or discomfort, we are likely to turn to the poultice, the compress, the hot water bottle or the electric pad. The general belief seems to be that the heat will relax spasm, aid digestion, and exert a beneficial influence generally. Can we prove experimentally the correctness of this belief, and if so, can we show how the effects are brought about? Unfortunately, the literature on the subject, though extensive, fails to afford much enlightenment. One thing seems certain, and that is that the effects are not due to an actual penetration of heat to the abdominal organs. Lüdin,[1] using an electropile on the stomach, found that the hottest poultice that the patient could bear, changed frequently during the course of three hours, raised the intragastric temperature at most 1°C. He fails to state whether the person experimented on was fat or thin. Stengel and Hopkins,[2] using a similar method, found practically no rise in temperature with hot water bottles left on for forty-five minutes. They were able to lower the temperature about 1°C. with ice bags. Carlson,[3] Boring and others have reversed the process, putting ice-water into the stomach and watching the temperature of the overlying skin. They found practically no change. Others have made similar studies with fistulas, with enemas, etc., and have found, as might be expected, that local differences in temperature are promptly evened up by the circulating blood. But even if the heat should penetrate to the intestine, it is far from clear how it would act there. Those who have studied the effects of heat and cold applied more directly to the bowel are not in agreement as to the results. We often apply ice to the abdominal wall in the hope of stopping gastro-intestinal movements, quieting inflammation, restraining hemorrhage, etc., yet there is little in the extensive reports of laboratory workers to encourage us in this usage, or to help us in deciding when to use cold and when to use heat. Most of the laboratory experiments indicate that cold stimulates peristalsis. Kelling,[4] however, found that even when he put ice-water into the stomach he could not increase the tone of that organ enough to influence any bleeding that might be present. Apparently we must continue to be disappointed occasionally in our efforts to affect peristalsis by these measures. When we do seem to get results it may be that they are brought about by way of the nervous mechanism connecting the skin and the internal organs. We must, however, be careful how we take refuge in realms in which theory is easy and exact demonstration is difficult.—*Journal American Medical Assoc.*

[1] Lüdin: Ztscher. f. d ges. exper. Med. 8: 68, 1919.
[2] Stengel and Hopkins: Am. J. M. Sc. 153: 101, 1917.
[3] Carlson: The Control of Hunger in Health and Disease, University of Chicago Press, 1916, p. 110.

Better Concrete–I*

Motion Picture Studies of Existing Conditions; Suggested Improvements

By Nathan C. Johnson, Consulting Concrete Engineer

When the Food Administration announced that "unstirred sugar left in America's cup would meet the needs of the world," the nation recognized a new responsibility. But, perhaps, even more startling, came the realization that enforced saving lost touch with privation through a more vigorous use of the commonplace spoon.

CEMENT WASTE

"Unstirred sugar" doubtless exists in all arts, but in none is it more apparent than in the art of concrete construction. There is no need to review *in extenso* known facts that make evident this particular instance of waste. The part played by concrete in daily life; the vast financial importance attaching to its wide use; its novel position as the one structural material made by unskilled labor with little or no regulation; its variable and uncertain quality, so that large factors of safety must be used with corresponding size of members at high cost; and, not least, the inefficiency of the composite, showing an average of one-fourth or less strength than the weakest of the substances that properly enter into it, with relatively poor endurance under many conditions of service, are so thoroughly recognized and have been confirmed so many thousands of times, both by laboratory experiment and in commercial trial, that the assumedly inevitable has found expression in "laws" descriptive of common results.

Yet, acceptance of these carries with it admission that further progress is impossible. Mind and pride refuse such confession of stagnation. Uncontrolled phases are known to be prevalent throughout the making of concrete. Until these are regulated and such regulation found of no avail, dicta as to futility of further effort cannot be wholly approved. Further, accurate and thorough knowledge of cement and concrete is at least not a general possession; and somewhere there may and must be "unstirred sugar" which, if activated, would change results.

Unstirred sugar! The phrase is suggestive both as to process and result. Photomicrographs of concrete are now familiar; and in them all, regardless of age, unused and impotent lumps of cement which perhaps, by more stirring, might have been made useful are a prominent feature (Figs. 7-9).

Common sense tells us that cement is necessary to concrete, for sand and stone without cement are but loose earth. Experience tells us that the more cement, the stronger and generally better is concrete. We know further that to make powdered cement of use, it must react chemically with water to form what may conveniently be described as a "liquid glue"; and that the concentration of this "glue"—the amount of cementing products carried in the mixing water—determines the value of the union between loose sand and stone. If, therefore, some of the cement is active, all might be active instead of remaining impotent, unless we, as users, plead circumstances as an excuse. And if we do that, we acknowledge responsibility, for "circumstance" means literally just "standing around."

ANCIENT AND MODERN CONSTRUCTION METHODS

It would seem a far cry from the houses of pagan gods to the commercial temples of today. What influence could captive Israelites, goaded and driven in sullen labor on the blazing Nile desert 4000 years ago, have on methods of the twentieth century? Cruel toil till death was the lot of Pharaoh's captives. It is to be presumed that they did what they must with no good will and no care as to outcome, yet their recorded ways are humiliatingly similar as processes to those practiced by free men in the year of grace 1918. In Fig. 1 may be seen an authentic record of building the Temple of Amon, at Thebes, in 1950 B. C.—the drawing of water in jars from a pond; the slaking of lime, made by burning limestone; the digging with a curious hoe (see Fig. 2) of sand from the desert to mix with this lime; the working of the mortar, also with such a hoe; the making of sun-dried bricks for facings; the hod carriers, with bricks and mortar; the masons laying the facing bricks, behind which was a mortar backing (denoted by the irregular line); and last, but not least, "inspectors" with ready rod and lash, driving on the task.

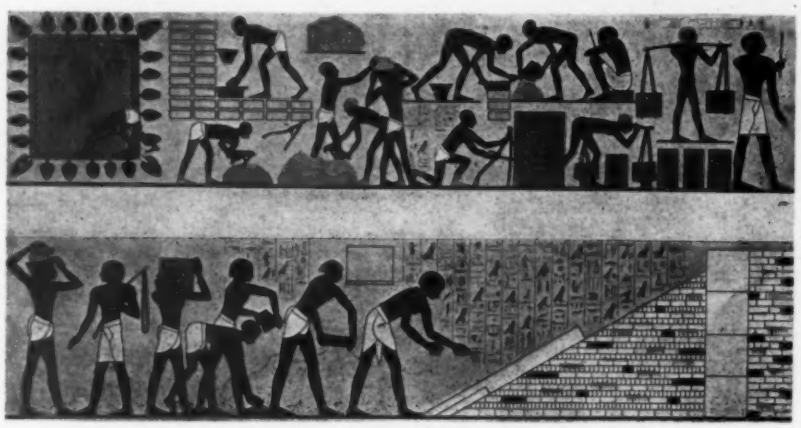


Fig. 1. Captives building temple of Amon, at Thebes, about 1950 B. C.
(From painting in temple after D'Avennes)

Fig. 2. Ancient hoe and mason's trowel from Egypt.

Slave labor and slavish ways. Can we also plead *force majeure* as reason for duplicating their ways in these times, as recorded in Fig. 5? Is all our boasted science of less avail than the ancient trade secret, whispered through the ages? And in spite of our better cements, ancients and moderns have achieved a result identical in many physical characteristics. In Fig. 6 is shown concrete from this ancient temple, bearing what we have come to call air voids and water voids and segregation; and in the 1918 concrete and all modern concretes, identical physical characteristics are molded, perhaps for our successors to gaze pityingly upon. For we have scant excuse.

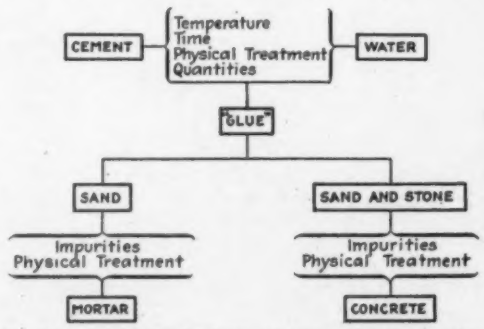


Fig. 3. Geneological chart of concrete and mortar.

We know these things to be detriments, where the captured slave neither knew nor cared. Are we guilty of slavish imitation, because we just "stand around," with idleness become by precedent a reasonable privilege?

CAUSES OF CONCRETE DISINTEGRATION

Nor is this exaggeration. On all sides are evidences of failure to make an efficient concrete, judged from the standpoint of its proper abilities. Even disregarding the size of members made necessary by factors of insurance against accident through failure of material unusually poor, one cannot but recognize that wherever there are concretes and particularly those subjected to moisture, whether from the air, or from fresh water, or from sea water, disintegrations of less or greater severity are in evidence. These may take the form of crazings, or of scaling, or of leaching, or of softening and crumbling. Yet, if we study evidences carefully, it becomes apparent that there is close similarity in all these phenomena. Crazings and most crackings, however intricate the final pattern, can be resolved into systems of 3, radiating from a common centre at approximately 120 degrees apart (Fig. 4). Scalings conform to like patterns, when pieced together; and leachings, which are antecedent to softenings, show first along planes of like form, or else follow a work joint. But interesting though this is as a clue, and though light is shed by recognition of like substances, such as drying earth, the chief interest is not in such faults of themselves, but in why they have centered at particular spots, leaving integral the surrounding material.

"SLACKER UNITS"

Although several possibilities for betterment are opened by speculation such as the foregoing, the size of a pinhole, or of a water void, or a crazing centring in either as compared to the whole of a massive structure in which they may be resident demands recognition. Of themselves, they seem insignificant. Undeniably, too, the structure is doing its work of supporting stress. Whoever saw it made will realize that thousands on thousands of yards of stone fragments, thousands of yards of sand grains of all sizes and hundreds of barrels of cement were employed in its building and must be now employed, as units of the mass, in resisting the total stress, divided into an infinity of parts. At least, it is assumed that each small part of the mass is so employed. If this is not so, some are idle; and idleness of a sufficient number of units might conceivably find expression as inefficiency of the associated units—i. e., weakness as a whole.

Further, since the majority of these units are minute, it is to be recognized they may be vitally affected in whole or in part by things minute, though collectively of great importance. It may even prove on examination that what to the eye are tiny crazings, of questionable import, may be vast chasms relative to the size of a cement grain, for instance, put into the mass as a medium for transferring stress from sand grain to sand grain, and that they may interpose impossible barriers to its functioning. Single air voids not uncommonly bulk larger than a dozen or more sand particles; and air voids are known to be present in vast numbers. Water pockets by the thousands in a single yard of concrete may cut off other would-be workers by the hundreds of thousands, and even sizable stones. If this is not fanciful, concrete is filled with slacker units, each of which was supposedly em-

*Paper delivered before the Engineer's Club of Philadelphia. Republished by courtesy of the *Journal of the Engineers Club of Philadelphia.*

ployed for all time to come when the concrete was mixed and placed in forms.

FACTORS AFFECTING THE FORMATION OF GOOD CONCRETE

To estimate the true significance of such possibilities it may be well to place in diagrammatic form the family tree of concrete as a preface to deeper study.

First and foremost in importance is the "glue" formed by union of the powdered cement of commerce with water. As this formation is a chemical reaction, it follows the laws of such reactions and is affected vitally by two variables—temperature and time. The first is particularly difficult of regulation in field operations; but the second, as well as a third variable, physical treatment, is possible of control. Obviously, also, the strength of the fluid cementing solution so produced will depend primarily upon relative quantities of the two reacting substances. In the family tree, therefore, as in all family trees, relationship is expressed by bracketing (Fig. 3).

To the "glue" thus formed, which has greater or less worth, according to the values of the variables affecting its formation, sand is added to make mortar, or sand and stone to make concrete, with, in each case, impurities, such as air, or other contaminating substances, and again physical treatment entering as factors qualifying ultimate value.

Fig. 5. Should this be the modern method.

THE ATTITUDE OF THE FIELD

But thus far no thought has been given to the components themselves — their nature, their habits and their prevalence in a mass, or to conditions prevailing at the time they became associated and are collectively and individually given their job.

The greater portion of the cement produced each year is used by those who have not highly technical knowledge, but who follow concrete work as a trade. The viewpoint of these men is well worth consideration, for it is their thought as expressed in handiwork, not in recommendations of committees, that is written large in the art today.

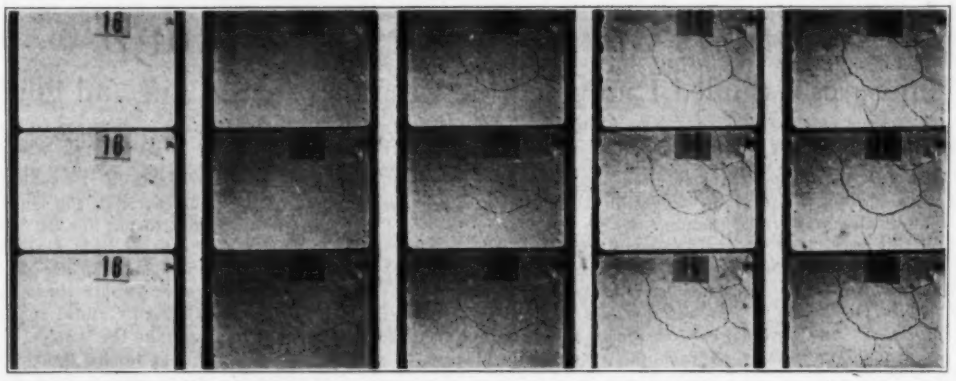


Fig. 4. Formation of three branched cracks in stucco caught by movie camera at one-second intervals

(Note that these originate at the surface pit seen in the upper right-hand corner)

With what inward intolerance must these men view "high-flown" specifications, descriptive of materials and methods! In spite of all these words, cement is, after all, just cement—a fine powder obtainable everywhere. It is rather costly, so as little as necessary should be used; and to prevent waste, it must be kept from dampness. Yet, even if it get lumpy, it can be mixed with sand and stone and water into a mass that has uniform color, that fills forms, and that makes concrete.

And sand! Everyone from infancy knows what sand is. It is a hard, strong and gritty natural product found nearly everywhere. Too fine sand is hard to mix, and coarse sand seems to make better concrete. Of course, it must be clean, or fairly clean. And it must be cheap.

Stone, of course, may be crushed rock or gravel. This, too, must be "clean," whatever that means. And it must be sound—that is, it must not break up into sand or clay while it lies in the pile waiting to go into concrete. After it is in the forms, no one can tell the difference for a year or two. The supply point should also be near the job, to cut down cost.

Water, of course, is necessary to make concrete mix easily and flow well into forms. Water for concrete comes in pipes, or may be had from wells, ponds, rivers or other natural sources. And there must be plenty of it.

To make concrete, take some proportions, such as one part of cement, two parts of sand and four parts of stone, measuring cement by sacks and sand and stone by shovel or wheelbarrow, with "just enough" water. Mix it by shovels or by machines. Then put it in the forms and tamp it or spade it. Then let it alone until it has set. After it is fairly hard, take off the forms. If there are any holes that would look so badly that the work would not be accepted, point them up with a little mortar.

SUPERFICIAL INSPECTION

Of course, inspectors and engineers bedevil things by rejecting sand and stone now and then, or by cutting down on water, though how they expect to get a good surface with dry concrete is hard to understand. Some of them make a big fuss over sand, but if they happen to be rushed, it is noticed they generally take what they can get. Others make a lot of cubes or cylinders from a batch three or four times a week; and they say these are smashed in some laboratory two weeks or a month afterwards. No one minds very much. They have to earn their pay; and when those blocks are busted there'll be ten feet or more atop the batch they took them from. And it is noticed that for all the fuss, the jobs where this is done look the same as those where the foreman runs the job, though maybe they cost more.

Yet, the man who—with much justice —feels like that, has actually noticed many other things about the substances he handles, without phrasing their significance. Subconsciously they influence him and direct his efforts. For instance, he knows that cement is hungry for water, so that it must be kept dry before use. Yet, for an hour or two after it is mixed, nothing seems to happen, for the mass remains as mushy to all appearances as when mixed. Shortly after it sets, or becomes rigid, and then gets harder and harder. Once in a while, though, cement comes along that sets very quickly; and in very hot weather the same things may happen with a "good" cement; but both seem all right in the concrete after it is once in the forms.

GYPSUM

Truly, it is not a workman's business to speculate as to causes. But the trained engineer, who is endeavoring to supply science "canned" into products and machines, knows that if cement were supplied as ground after burning in kilns, it would be so hungry for water that reaction with mixing water would take place too quickly; and to avoid this, manufacturers add gypsum, which is hydrous, or water-bearing calcium sulphate, to the still hot cement. This heat drives off water from gypsum; and this water, spreading as steam, reacts with the hungry cement particles, forming over their surface a very thin, protecting skin of dead, or hydrated, cement, which for a time (depending upon the thickness of this skin and the temperature) resists pene-

(*Continued on page 251*)

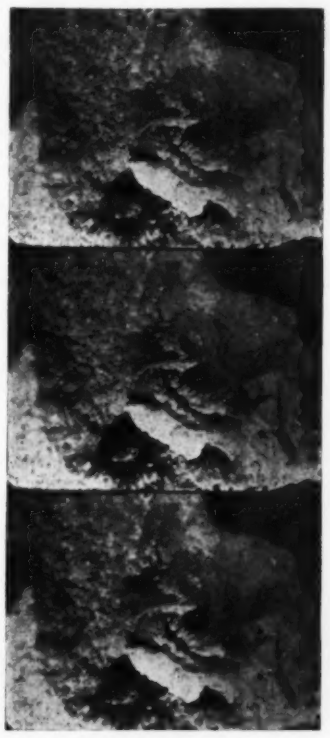


Fig. 6. Concrete made in 1950 B. C. Showing segregation, air voids and water voids common to ancient and modern concrete.

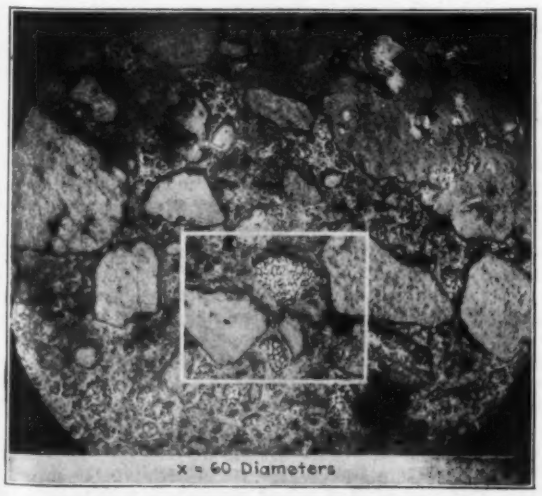


Fig. 7. Photomicrograph of commercial concrete showing sand grains, unused cement and air voids.

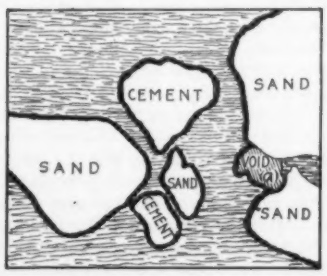


Fig. 8. Relation of cement, sand particles and water shown in Fig. 9.

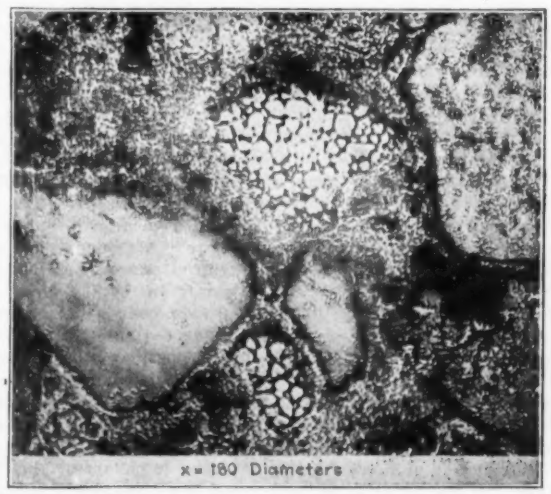


Fig. 9. An Enlargement of the section limited by lines on the photomicrograph at the left (Fig. 7.)

What is an Incandescent Lamp?

Vacuum versus Gas-filled Lamps and the Relation between Life and Efficiency

By R. W. Shenton

As judged from experience with several thousand visitors to our plant, there is considerable mystery surrounding the making of incandescent lamps, and, apparently, much which proves of interest. This article has been prepared with a view to giving those who cannot visit a lamp manufacturer somewhat the same "line-up" that the actual visitor receives.

To begin, let us wipe the slate clean and forget whatever present knowledge of incandescent lamps we may have, and go back two or three generations and work with the tools available at that time. We have a notion that we can make a lamp based on the principle of incandescence, but have nothing to start out with except the knowledge of a few fundamental principles.

One bit of information we have to start with is the knowledge that a red-hot poker gives off light. A white-hot poker gives off more light. This is incandescence. We see that if some means can be found of keeping the poker hot without having it buried in a bed of coals, we will have a crude incandescent lamp. Electricity supplies this means, for it was a matter of common knowledge among early electrical experimenters that passing a current through a conductor heats that conductor, and as long as the current is flowing we are continuously pumping heat into the conductor. If the current is sufficiently large with respect to the size of the conductor, the latter will be heated to incandescence. Therefore, if instead of a poker as our incandescent element, we use a fine strand or filament, say of iron wire, heated by an electrical current, we will have a simple electric incandescent lamp.

At this stage we encounter our first obstacle—when we force enough current through our filament to make it an effective producer of light, we find that the filament is soon consumed, burns up or "burns out," as we say in the modern vernacular. Even metals will burn up like so much wood when heated to very high temperature, as is witnessed by the fact that the blacksmith has to be extremely careful when heating a piece of iron to white heat, otherwise, when he tries to find it with his tongs, it will not be there.

Up to this point we have an incandescent lamp which will last for a few seconds. Our problem now is to prevent the filament from burning up. When we speak of anything burning, this is simply another way of saying that it combines with the oxygen in the air. If there is no oxygen present, there can be no combustion. Therefore, to prevent burning we propose to keep all oxygen away from the filament. We can provide for this condition in one of two ways—we can enclose the filament in a glass bulb and remove all the air from the bulb so that the filament will operate in a vacuum; or, we can fill the bulb with some inert gas, that is, some gas which does not contain oxygen or any other element that will enter into chemical union with the filament. We try both methods, but we soon find that when we enclose our simple filament in a bulb filled with some such gas as nitrogen, it takes more current to keep the wire hot than it does in the case where a vacuum is used. The reason is that this gas in the bulb provides a direct path for the heat to escape from the filament and consequently an additional supply of current must be provided to keep the filament up to the proper degree of incandescence. (Edison is said to have experimented with gas in the bulb when he brought out his first incandescent lamp, but, among other things, these heat losses made the use of gas prohibitive.)

The vacuum lamps were used for a number of years, as the reader knows. Perhaps very few of us have ever stopped to realize just what a vacuum is and what the conditions in a vacuum are. A vacuum is an extreme state of nothingness with all surrounding atmosphere trying to force its way in, with a force behind it of something like fifteen pounds to the square inch. The matter of sealing the bulb so as to exclude air throughout the life of the lamp was for a long time the chief bugbear of earlier lamp makers, and is today a step in lamp manufacture calling for extreme care. Not only must the bulb be air-tight, but it must be able to resist mechanically this external pressure tending to make it collapse. Here the fact that the bulb is round is a life-saver, for a rounded surface is able to withstand a very high uniformly distributed pressure, as is seen in the ordinary stone arch bridge, and pointed out in the often cited but less frequently tried statement that it is impossible to crush an egg between palms of the hands.

The conditions that exist in a vacuum-are an additional handicap to the lamp maker. Absence of atmospheric pressure is in a way equivalent to suction. When we take any object or material which we are used to seeing and handling every day and place it in a vacuum, we virtually place it in another world, a world where we find lacking this powerful pressure of fifteen pounds to the square inch, which we have become so accustomed to that we hardly realize it exists. We can easily imagine the increased tendency of materials to come apart and disperse into the gaseous state when deprived of the usual fifteen pounds to the square inch pressure.

A mild case of this decreased pressure is illustrated in the increased blood pressure of persons ascending to high altitudes; in this case the decrease in pressure is very small compared with that necessary to constitute a vacuum. It would require an Edgar Allen Poe to attempt a description of the physiological and psychological effect of even a partial vacuum on a human being. In a vacuum, materials will vaporize at a great deal lower temperature than in the atmosphere. The thin filament of an incandescent lamp heated to a high temperature as it is, and in a vacuum, is particularly liable to vaporize, and indeed whenever the lamp is turned on, infinitesimal particles are flying away from the filament and depositing on the bulb. In the case of a lamp filament we have the undesirable combination of heat which tends to disperse molecules of matter and the absence of atmospheric pressure which would help to hold them together. Notwithstanding all these difficulties, we

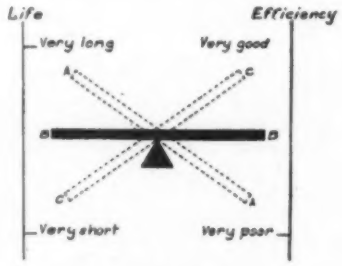


Fig. 1. Relation between Efficiency and Life

are gratified to find that our lamp operated in a vacuum is practical.

We have an incandescent lamp and it works! We are now, however, confronted with a new problem which must be solved before the lamp is ready to be used commercially. What voltage shall we apply to our lamp in order to obtain the best service? We find that the higher the voltage impressed on the lamp, the hotter the filament becomes and the better the efficiency of light production. If we raise the voltage to such an extent that the temperature of the filament is just below its melting point, we get the maximum possible light emission from this particular lamp and a maximum efficiency of light production; but our lamp will stand up only a very short time under such operation, due to the rapid vaporization of the filament which will take place. On the other hand, if we lower the voltage to such an extent that the filament barely glows a dull red, we have a lamp that will last almost indefinitely, but will be a feeble and inefficient light producer. It is necessary, therefore, for us to strike an economic balance between these two factors—very high efficiency and short life on one hand, and very low efficiency and long life on the other, and thus to conclude how high a voltage rating we can give the lamp; that is, how efficient we can make it and still get a life that will be satisfactory. The see-saw diagram in Fig. 1 illustrates in a general way this relation between efficiency and life. The fact that an improper balance was arrived at in rating some of the early carbon lamps, as indicated in *AA* in the figure, accounts for some of these lamps still being in service today. When such a lamp is exhibited with the remark that it has been in use for twenty or thirty years and that "they surely made them good in the old days," the speaker sees only one side of the see-saw chart and overlooks entirely the fact that the lamp has been wasting enough current to pay for fifty or a hundred new lamps giving the same light for a great deal less current. It is not a trade secret that lamps could be made to last ten or twenty times as long as they do, provided we wished to ignore conservation of our fuel supply and to make the lamp user pay out several times as much money for his light as he now does. The point is that every time a lamp user spends a dime for lamp renewals, he spends a dollar for electric current and saving on lamp renewals at the expense of efficiency is indeed a case of spigot economy and bung-hole extravagance. It is for reasons pointed out in this paragraph that improvements in lamp manufacture do not as a rule result in longer-lived lamps but rather in lamps of improved efficiency.

Coming back to our original line of discussion it is, of course, necessary for us to decide upon some particular filament material to use in our lamp. Iron was mentioned simply by way of illustration. We adopt carbon because it has a higher melting point than any other material that we would consider using. Later carbon is superseded successively by tantalum and tungsten, materials having lower melting points than carbon, but having, also, lower vapor tension than carbon—that is, while they melt at temperatures lower than the melting point of carbon, the tendency of their molecules to disperse and fly apart at operating temperatures is not as great as in the case of carbon. This means that for a given lamp life, filaments of these materials can be operated at considerably higher temperatures than carbon and consequently at much better efficiencies. While the adoption of these new filament materials is epochal from the standpoint of efficiency of light production, the basic principles employed are the same as for the first commercially successful lamps.

For about thirty-five years all incandescent lamps were made in accordance with the methods just discussed. Then comes the coiled filament, originally developed for the purpose of getting a long filament into a small space, either to make it possible to get the filament into a bulb of restricted dimensions or to concentrate the light source for focusing purposes. With this coiled filament and the theory, discarded years before, of using a gas to do away with disadvantages resulting from operating the filament in a vacuum, we produce what is known as a C lamp. It will be remembered that the reason we discarded the gas theory in the earlier lamps was that the gas provided too good a path for the heat to escape from the filament, while on the other hand the vacuum was almost a perfect insulator of heat. The coiled filament enables us to concentrate and condense our filament at the center of the bulb so that the surface is less freely exposed to the surrounding gas and the heat loss through the gas thereby greatly reduced. The principle is the same as that which makes it possible for a herd of sheep to keep themselves warm on a cold day by huddling together and thereby reducing their exposure to the air—reducing the surface exposed to the wind whereby the heat of their bodies is transmitted to the surrounding atmosphere. We still have the heat losses that were present in our early experiments using gas in the bulb, but they are greatly reduced, and the C lamp is more efficient than the B; in spite of the losses and not because of them.

For the sake of a clear understanding of this phase of the subject, we will say that the amount of heat lost through the gas is the same for a 25-watt lamp as for a 1,000-watt lamp, although this is only very roughly true. We see then that in the case of a 1,000-watt lamp the loss of heat and therefore the extra current that we have to supply to the lamp to make up for this loss is only a drop in the bucket when compared with the total current and the increased efficiency due to being able to operate a filament at a much higher temperature than we could in a vacuum. (The higher the filament temperature, the greater the proportion of energy transformed into light and also the whiter the light.) This loss of heat which we say is a drop in the bucket in the case of a 1,000-watt lamp becomes more and more important as we go down the line to lower wattage, and in the case of a 100-watt

lamp it begins to be appreciable, so that the 100-watt lamp is considerably less efficient than the 1,000-watt lamp. Sooner or later we come to a point where the proportion of the total wattage of the lamp required to take care of this heat loss is great enough to balance the advantage of the higher filament temperature made practicable by the use of gas. When we come to this point there is no advantage in using the gas other than that the light from a gas-filled lamp is whiter than that from the vacuum lamp. This is the reason that there is a lower limit of wattage below which it is not advantageous to make C lamps.

A C lamp of so low a wattage that it would have exactly the same efficiency as a B lamp of the same wattage would none-the-less give a much whiter light, in fact practically as white a light as that of the most efficent C lamp. We must not be confused by the thought that, since the filament of the C lamp in this case loses more of its heat, because of the gas, than does the filament of the B lamp, the filament of the former is cooler than that of the latter. It is true that the gas-filled lamp loses heat, but the lamp is so designed that extra wattage is supplied, as a portion of its wattage rating, to overcome this heat loss; it is this extra wattage that must be supplied that pulls down the efficiency of the C lamp so that it is the same as that of the B lamp.

To summarize, an incandescent lamp is essentially a filament of some material suitable to withstand high temperatures without too rapid vaporization. It gives light by virtue of its being heated to incandescence by an electric current. To prevent this filament from oxidizing or burning up, it is operated either in a vacuum or in an atmosphere of inert gas. In a vacuum it suffers by reason of the absence of a pressure to hold it together and to counteract a tendency for it to fly apart or vaporize. This difficulty can be overcome by the use of a gas in the bulb, which makes it possible to operate the filament at a great deal higher temperature without undue vaporization, but a new disadvantage results in the form of heat losses through the path provided by this gas. This loss is small enough so that it nowhere near offsets the gain in efficiency resulting from higher filament temperature as far as larger sized lamps are concerned, but in the case of smaller lamps the wattage thus lost would make gas-filled lamps actually less efficient than vacuum lamps.

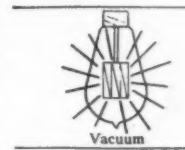
In this article the object has been to simplify the theory of incandescent lamp manufacture. While the basic theory is simple, it is needless to point out that the practical refinements required are legion. It takes a great deal more than a glass-blower and a spool of tungsten wire to make a good lamp. This article might be classed as parallel to one describing the operation of an automobile in a single chapter, by showing how the explosion of gasoline vapor can be used to produce a reciprocating motion, and this motion in turn utilized to make the wheels go around.

Fig. 2 will serve to demonstrate in a practical way the theories just discussed. As indicated, many of the data given are approximate, since it would involve considerable time and expense to make accurate determinations of some of the figures, which for the purpose in hand would be of little or no added value over the estimated values given.

For the first case, let us assume that we have an ordinary 100-watt B lamp. This lamp, operated at rated voltage gives us 1,000 lumens of light in return for 100 watts of electrical energy and will continue to do so for 1,000 hours Suppose now that we take this same lamp and fill it with an inert gas, as indicated in cut No. 2. We find that when we impress the rated voltage of our original lamp, 115 volts, on this new lamp, that the filament gives only 15 spherical candle-power and that the life is, of course, indefinitely long. This lamp operated under these conditions is not a satisfactory producer of illumination.

Noting that our life in the case just referred to is indefinitely long and that our filament is not heated to the point of being a good illuminant, we realize that this second lamp should have a good deal higher voltage rating. If we raised the voltage on this lamp we would find that at a voltage of 185 it would have a filament temperature corresponding roughly to 1,000 hours' of life and would take 230 watts, in return for which it would give us 1,850 lumens. This lamp would in both cases be inferior to the vacuum lamp we started out with. The reason is, of course, that the gas carries away so much of the heat of the filament that an additional voltage is needed to pump an additional wattage into the filament to keep it at a temperature that will make a good light producer. So far our attempt to improve on the B lamp is a failure.

Let us see what coiling the filament will do. Suppose it is possible for us to take the same filament used in lamp No. 1 and coil it as indicated, again filling the bulb with inert gas. Upon impressing 115 volts on the lamp, we get 850 lumens in return for an expenditure of 95 watts. This is not as good an efficiency as we obtained with our original lamp. We would find, however, that this lamp would live something like 10,000 hours, which indicates that we can stand for a higher voltage, which will give us a higher efficiency. As indicated in case No. 5, 135 volts would give 1,000 hours' life, a wattage of 125, and a lumen output of 1,570. This is an appreciably better efficiency than obtained with the B lamp. What we now have is a 135-volt, 125-watt, gas-filled lamp. To make a 115-volt, 100-watt gas-filled lamp, it would be necessary only to change the filament dimensions in accordance with known relations based upon manufacturing experience.



No. 1—Ordinary 100-watt B Lamp.
115 Volts
100 Watts — 10 Lumens per Watt
1000 Lumens
1000 Hours' Life

No. 2—Lamp No. 2 Filled With Gas.
115 Volts
115 Watts — 1.6 Lumens per Watt
190 Lumens
Indefinitely Long Life

No. 3—Same Lamp as No. 2 With Voltage Raised.
185 Volts
230 Watts — 8.0 Lumens per Watt
1850 Lumens
1000 Hours Estimated Life

No. 4—Same Lamp as No. 2 or No. 3 Except Long Filament is Coiled.
115 Volts
95 Watts — 8.9 Lumens per Watt
850 Lumens
10,000 Hours' Estimated life

No. 5—Same Lamp as No. 4 With Voltage Raised to Give 1000 Hours' Life.
135 Volts
125 Watts — 12.5 Lumens per Watt
1570 Lumens
1000 Hours' Life.

Fig. 2. C Lamp Theory—The values are approximate

The Rodent Menace.

Civilisation is daily teaching us that we are members one of another, and this applies especially to our failings and failures, and even to our diseases, for one carries the germ and another catches it. On the animal kingdom we are still more intimately dependent, for they frequently act as hosts to our infections during inhospitable intervals. What should we know of malaria if it was not for the mediation of the mosquito, or of plague if it was not for the rat? And the rat is becoming ever more and more suspect. In regard to protozoal parasites it has been long known to harbour the *Trypanosoma lewisi*, an apparently harmless guest. The Japanese have shown the rat to be the host of two other protozoa which, while harmless to itself, are capable of causing serious illness in man. These are the *Spirochaeta icterohaemorrhagiae* Inada and the *Sp. morsus muris* Futaki. The work of Inada, Ido, Hoki, Kaneko, and Ito, on the first-named has since been confirmed by the demonstration of rat carriers in France, Belgium, Algeria, and the United States of America. In England the presence of the specific spirochaete of haemorrhagic jaundice in the rat was not fully proved until the investigation of Major A. G. R. Foulerton, carried out in the Hygiene Department of University College, London, and recently printed at th instance of the Public Health Department of the Corporation of London. Major Foulerton examined 101 rats caught within the City and Metropolitan area, and in 4 of them found a spirochaete which killed a guinea-pig on the twelfth day with all the characteristic appearances of spirochaetal jaundice. Three of these rats were from a batch of twelve caught at a general store in the City last November; the fourth from a batch of seven from another part of London. Dr. A. C. Coles stated in our columns[1] last year that he had found spirochaetes resembling the *Sp. icterohaemorrhagiae* in 9 out of 100 rats caught in the neighborhood of Bournemouth, and gave excellent micro-photographs of the protozoa, but he did not proceed to confirm his results by animal inoculation. Major Foulerton discusses the method of transmission of the protozoon from rat to rat and rat to man, inclining in the first case to accidental inoculation, in the latter to the infection of food and drinking water. For the present the rat-flea has nothing to say to this matter.

In a presidential address, delivered last year before the Royal Society of New South Wales and since reprinted and circulated, Dr. J. Burton Cleland pointed out that a town that lets its rats multiply is exposed to a menace that may lead to enormous financial losses and possibly a heavy death roll. Rats live a communal life in direct contact with each other, and thus the passage of any pathogenic organism is facilitated, while in the passage the pathogenicity of the less lethal forms is probably increased. He went on to discuss rat leprosy, which is widely distributed, though of relatively rare occurrence, its incidence among the rat population in New South Wales being much about the same as the incidence of leprosy amongst the human population. From investigations on its occurrence in rats it might be inferred that there is one diseased rat in Sydney for every 100,000 examined, whilst in New South Wales there is approximately one leper to 80,000 inhabitants. The question arises as to whether there is any possible connexion between the two diseases, whether, indeed, they are not due to the same organism. Dr. Cleland sketches the phylogenetic history of the tubercle bacillus, showing that it was originally a saprophyte, as, for instance, the acid-fast timothy-grass bacillus is still; the next stage being its accidental introduction by the alimentary canal or through wounds into the tissues of vertebrates, where it has found itself capable of living and multiplying, even though in such an unusual environment; finally, being given frequent opportunities of escape from its host through ulceration of the lungs and of introduction consequently to fresh individuals, its pathogenicity has been increased and its saprophytic qualities have been diminished or lost. The rat leprosy bacillus may, he suggests, be in somewhat the same transition stage.

These are new aspects of the rodent menace about which sufficient is known to demand the more active measures of suppression in this country. The Rats Orders of 1918 and 1919 gave local authorities the liberty to organize local campaigns. Several county councils have appointed official rat-catchers. In Leicestershire a summer campaign resulted in the death of 125,223 rats, for which a sum of £1525 was paid out. The Board of Agriculture has, in harmony with a growing habit, suggested a "rat week" for Oct. 20th-27th, in which village communities should compete one against the other in baiting, trapping, and ferreting. All this is to the good, but we doubt the attainment of the end in view so long as slack authorities are not gently urged by legislative action; for rats harried on one side of a boundary can take refuge on the other side where the human community is more lenient. We regret that Lord Aberconway's Rat Destruction Bill did not become law. It is for the Ministry of Health to devise appropriate legislative action which shall not be held up by lack of time or interest in the Chamber.—From *The Lancet*.

[1] *The Lancet*, 1918, i., 468.

A recently patented machine for manufacturing glass wool consists of an electrically heated melting vessel of tungsten, iridium, or an alloy having a high electrical resistance. The glass is drawn through apertures in the top of the melting pot on to a rotating drum, the flexible rim of which yields as the wool cools and contracts when wound thereon.

Refinements in Turbine Design*

Some Details that are Open to Improvement

By Prof. A. G. Cristie, Dept. of Mech. Eng., Johns Hopkins University

REPORTS of tests of large steam turbines that appear from time to time in the technical press show progressive advances in steam-turbine design. Steam consumption in pounds of steam per kilowatt-hour is quite low in some cases, though this is partly due to increased steam pressures and superheat and to high vacuum. The increase of the efficiency ratio referred to the Rankin Cycle has, however, been the best means of judging the improvements and refinements in design, and this ratio has increased practically since turbines were first built. The efficiency ratio on some recent turbines has reached a comparatively high value, and this leads one to consider the line of future turbine development that can still further increase this ratio.

Before entering into a discussion of the possibilities in this direction, it is well to direct attention to some factors in the relation of efficiency ratios and commercial steam-turbine design. A high efficiency ratio in a turbine indicates that its losses are reduced to a small amount through clever design of parts, through the use of small clearances and usually through the use of many stages. This means a large, expensive, carefully built machine which requires care in operation. On the other hand, its high economy makes it very desirable when its load factor and use factor are high and coal is expensive.

Such a high grade machine is not necessary or desirable for many services, particularly when coal is cheap, load factor and use factor low, and skilled operators not available. Hence, maunfacturers furnish smaller, more compact, cheaper machines for such services in which clearances are larger, reliability increased, and the efficiency ratio is held only at a moderate figure. These machines give good service with little expert attention and serve the purpose for which they were designed.

The war has projected into the problem of steam-turbine design two new factors which are sure to have considerable influence on future machines. These are increased fuel costs and increased labor costs. Apparently, the power-plant operator can do little to decrease these costs under present conditions, so that if he is to reduce his production cost of power, he must look to a higher efficiency in main power units. In this article it is intended only indirectly to indicate the possible economies in the use of fuel through securing higher efficiency ratios in steam turbines and thereby decreasing the fuel consumption. The following paragraphs will therefore briefly suggest some further refinements in steam-turbine design that may secure the desired results.

It is hardly likely that the efficiency ratio can be greatly increased in a given turbine by a modification of any single factor in design. Improvements must be sought in refinements of the design of many of the turbine elements, a few tenths of 1 per cent. here, a few more tenths there, and still a few more tenths in several other places, which in the aggregate may result in marked improvement in the total efficiency ratio of the unit. These small amounts will be secured largely as the result of extended research, test and study of design. The expense of such development work often prevents some companies from undertaking it, but competition will force many to do much of this in the near future.

Probably more experimental work has been done on nozzles than on any other turbine part. Their efficiency is fairly high, ranging from 88 to 94 per cent. There is still an appreciable margin for improvement in this efficiency. As a nozzle alone the circular throat and mouth give the most efficient form. When the delivery of the jet upon the turbine blades is considered, the two ends of the jet from an eliptical nozzle mouth do not completely fill the blades they enter and eddies are set up. This is overcome with a rectangular mouth. Should the nozzle therefore have a square throat and rectangular mouth, or a round throat and rectangular mouth, and what should be the relative length, flare of sides and size of mouth for various diameters of throat and ranges of expansion? Further experimental work on nozzles in the light of Martin's recently published theory offers some possibilities for the improvement of nozzle efficiency.

*From *Power*.

In multiple-stage impulse turbines the orifices in the diaphragms usually consist of sheet-steel partitions bent to form and cast in place. These seldom have a high polish and in any case corrode more or less in service. Friction losses would be decreased were these made of a brass or bronze that could be highly polished and would retain the polish. Furthermore, there is reason to believe that a certain amount of eddying takes place in these orifices which might be prevented if the rear of the orifice were flattened out to conform to stream lines in the same manner that blades are thickened at the center. Such built-up orifices have been used by one manufacturer, and improved results are reported.

Friction losses in steam jets crossing blades are very difficult to determine accurately. The condition of the blade surface, whether rough or smooth, is an important factor. The correct width of blade is another factor. A wide blade would appear to reverse a jet with least shock, but the added length

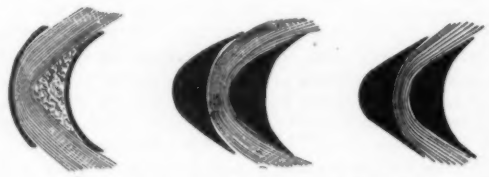


Fig. 1. Behavior of jets in blades.

of wall increases the surface friction. A narrow blade may cause shock and eddies by too sudden reversal. The blade must be wide enough and thick enough at the center to withstand shock and keep vibration to a minimum. The thickness of the blade at the center and the stream-line effect of the flowing jet are factors deserving much attention. Apparently, much study can still be devoted to blading material and blade shapes.

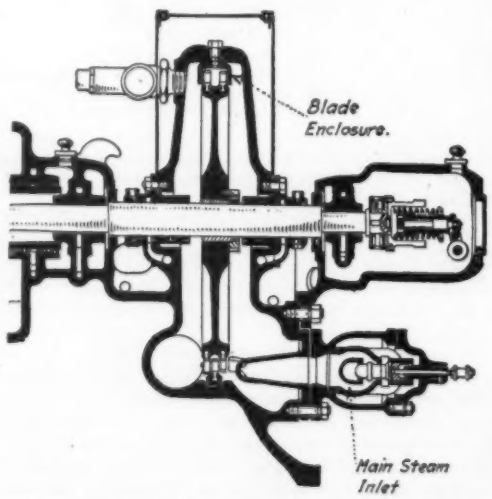


Fig. 2. Sectional view showing blade enclosure.

Several companies building impulse turbines have adopted the practice of increasing the inlet angle of the blades beyond that required by the velocity diagram. In England this is said to have practically no effect on economy at full load and seems to improve performance with low steam pressure or at light loads. A study of the effect of shock on moving blades will indicate how far this inlet angle may be increased to advantage.

The thickness of the inlet and outlet edges of the blades has been varied over wide ranges. Usually, this thickness has been governed by manufacturing and mechanical requirements rather than by a consideration of the effect of shock on the steam jet. The edges must be thick enough not to wear away rapidly from erosion or corrosion. Too thin edges do not make strong blades. Most impulse blades now have a distinct thickness on the inlet side. Here, again, a study of shock on blades might indicate a form of blade edge that would conform more to divide stream lines of the flowing jet and thus lessen shock at this point.

Several turbine builders, both in this country and in Europe, have made it a practice to give a high polish at all interior portions of their turbines that are exposed to moving steam. This is an excellent plan and could be adopted by all builders.

In impulse turbines the friction losses of the disks are of considerable magnitude, particularly in the high-pressure stages. The whirling losses due to churning in the blades which are not filled with a steam jet are also relatively large in the high-pressure sections of the turbine. European designers are said to be building their diaphragms so as to inclose the disks and blades more tightly than heretofore. One American builder has inclosed the rotating blades that are not opposite nozzles by a U-shaped cover to decrease this whirling loss. Another manufacturer uses a small-diameter disk on the first stage and allows the disk diameter to increase progressively to the last stage. This lessens the disk friction in the early stages when the steam is more dense and also decreases the ratio of empty to steam-filled blades on the disk. There are, therefore, some refinements possible in the disk and diaphragm design that may appreciably decrease the whirling losses.

Cast iron is subject to growth when continuously exposed to high temperatures. Hence, the high-pressure cylinder section and diaphragms of turbines using high pressure and superheat must be made of cast steel thoroughly annealed. This is expensive construction, but must be used to avoid accidents resulting from distortion due to the growth of the cast iron.

A water gland consists of a small centrifugal pump impeller fixed firmly on the turbine shaft and designed to maintain a solid band of water under a pressure of 10 or 15 lb. around the periphery of the impeller. This band of water prevents air from leaking into the exhaust ends of the cylinder casing. As a centrifugal pump its efficiency is low, and generally little attention is given to the design of the impellers to get improved efficiency. The power required to drive this pump may be materially reduced by giving it the careful attention that a high-grade centrifugal-pump design involves.

Labyrinth packings are used extensively for casing glands and diaphragms. Some experimental work abroad showed that there was a great difference in the steam leakage past various forms of labyrinth glands. These forms of glands have only recently received much attention in this country. Improved designs should decrease gland leakage materially.

All the earlier labyrinth glands had the labyrinth teeth cut on the stationary element. If a serious rub occurred it was on a portion of the rotating shaft where quite excessive heating often developed which frequently resulted in a sprung shaft. This design is wrong. A much better plan now being adopted by an American manufacturer is to cut deep, thin labyrinth teeth on the rotating shaft, leaving the diaphragm comparatively smooth. If a rub now occurs, the fine teeth dissipate the heat before it reaches the shaft proper. There is less chance for local overheating to spring the shaft, and there is also more opportunity to introduce improved gland constructions.

The efficiency of the Parsons turbine could be considerably increased if leakage losses over the ends of the blades could be diminished. The clearances over the ends of these blades are fixed by mechanical considerations and probably will not be decreased beyond present practice. It is questionable whether any shroud device with labyrinth packing over the blade tips would decrease leakage sufficiently to offset the increased whirling losses. However, the labyrinth packings on the sides of blades in the Ljungstrom turbines suggest some similar construction for Parson units which may eventually be worked out to decrease leakage losses.

For highest economy the blade speed in impulse turbines should be about 45 per cent. of the steam speed and in the Parsons turbines about 90 per cent. These values are not realized in practice, for to do so either the steam speed must be low and the number of stages large or if the number of stages

is to be few the wheel speeds become too high. Many stages mean large expensive turbines, hence designers have aimed toward higher wheel speeds. Large turbines with blade speeds of 860 ft. per sec. are operating. If this figure is to be exceeded, some form of alloy steel must be employed for disks and blades which will safely withstand these heavy strains. Some designers prefer quite moderate speeds, sacrificing economy to safety. There is every probability, however, that blade speeds will be increased as experience in steam-turbine materials accumulates.

Vibration in turbine blading is still one of the engineer's most difficult problems. Little is known of the theoretical nature of this vibration, though it is generally assumed to be of the nature of a harmonic. Does the blade act like a beam held at one end and uniformly loaded? If so, what is the effect of the shroud and of intermediate lacing? Finally, does it have a period of vibration due to the steam velocity? If the theoretical anayises were fully developed, engineers would be able readily to devise means for overcoming vibration.

Parsons turbine design presents quite another set of problems to that of impulse turbines. Reference has already been made to water glands and to leakage over blade tips. Leakage past the balance piston is a source of loss that may be reduced. The form of dummies in such pistons may be subject to modification so that this loss can be considerably diminished. One form proposed carries several faces on each dummy which cause repeated throttlings as the steam seeks to leak inward over the dummy.

Parsons blade forms are largely the result of cut-and-try methods. The front and rear curves of the blades, the effect of thickness at the entering and leaving edges and the reinforcing of these blades against vibration are matters demanding further study by the engineer. In reference to the effect of thickness on the outlet side, British engineers are inclined to believe that this has no effect on stream flow. American designers believe that it has some effect and generally make allowance for this thickness.

Another theoretical consideration in Parsons' design is the effect of the carry-over velocity from one row on the succeeding row. Does the jet continue into the next row at the absolute leaving velocity of the preceding row, or is this velocity reconverted into heat and thus partly lost as reheat? Apparently, part of both these effects takes place, though to what extent is not definitely established. If the jet can be continued without reheating effect, a possible gain might result.

The wear of blading materials is an important consideration. Many troubles with blade failures have led to an intensive study of blade materials. The first and last blades usually are subject to the most extreme conditions. The first have to withstand high temperature; the last are subject to wet steam and at the same time high centrifugal forces and sometimes to severe vibrations. Much remains to be done to develop the best materials for these two extreme conditions. At present no material seems available to fulfill all the desirable requirements of either.

The preceding paragraphs outline briefly some of the problems of steam-turbine design that are occupying the attention of engineers. Owners and operators of turbines are interested in their further development.

Heterodyning Wavemeter.

By Lieut. J. Scott-Taggart, M.C., R.E.

The development of continuous-wave wireless telegraphy has necessitated a special instrument capable of measuring the waves used. The ordinary wavemeter used for measuring the damped waves, transmitted by spark wireles stations, consists of a single variable oscillatory circuit, shunted by a crystal detector and a pair of telephone receivers. The waves are sent out in groups or wave-trains from the transmitting station, and influence the wave-meter oscillatory circuit, provided the latter is tuned to the same frequency as the transmitted signals. The groups of oscillations which are set up in the wave-meter are rectified by the detector producing unidirectional pulses through the telephone receivers. These pulses, occurring rapidly and at regular intervals, produce in the 'phones a buzz having a note-frequency equal to the spark-frequency of the transmitting station. The wavemeter is generally tuned to the transmitted signals by means of a variable condenser graduated in wave-lengths or degrees, in which latter case a calibration chart is used. When the loudest signals are heard in the 'phones the reading given b ythe condenser indicates the length of the waves being transmitted. This method is necessarily somewhat crude, since it relies very largely on the personal element; it is always difficult to decide the point where the signals are loudest, particularly when the peak of the transmitted wave is not very sharp and signals appear to be the same strength over a considerable range of the condenser scale. None o fthese difficulties are met with when measuring continuous waves by means of the heterodyning wave-meter described below. The greatest accuracy may be obtained, the only personal elemnt consisting in diffrentiating between a high and a low note—a very simple matter.

*From *The Electrician* (London).

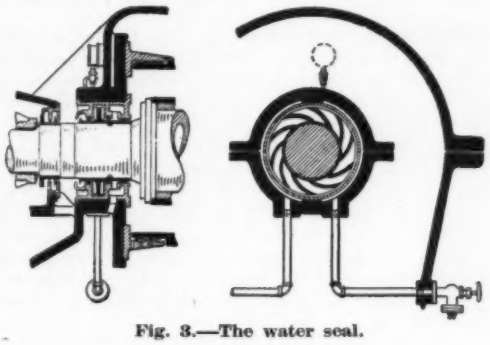


Fig. 3.—The water seal.

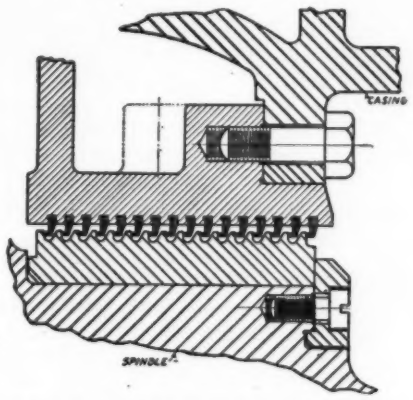
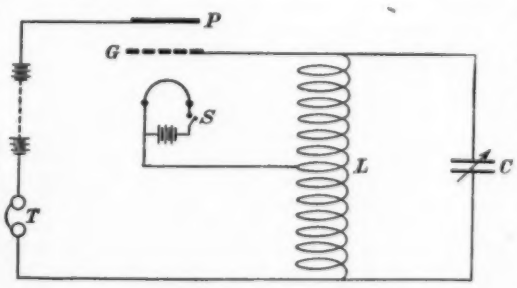


Fig. 4.—Labyrinth packing in section.

Although an ordinary spark wave-meter is not designed to measure continuous waves, yet it is not incapable of doing so. If such a wave-meter be brought near a continuous-wave transmitter the key of which is depressed, sustained oscillations of constant amplitude will be set up in the wave-meter circuits. These oscillations are not broken up into groups, as in the case of spark signals, and, therefore, when rectified by the detector, merely produce a steady flow of current through the telephones. Nothing will b heard except clicks at the commencement and end of the stream of oscillations. If, however, dots are sent on the transmitting key, clicks will be heard in the 'phones, and will be loudest when the wave-meter is tuned most accurately to the transmitted waves, the maximum energy being then received. Anothrr method would be to break up mechanically, by means of an interrupter, the steady flow of current through the telephones. These methods, however, are unscientific and inaccurate and give only very rough results.



Heterodyning wavemeter.

The accomjanying drawing shows an instrument sound and accurate both in theory and practice. It consists, in effect, of a simple valve circuit suitable for the reception of continuous waves. The plate P of a vacuum valve is connected to the positive of a battery of small dry cells having a total voltage of about 20 volts. The negative end of this battery is connected to one side of a pair of low-resistance 'phones, the other side of which is connected to the end of an inductance coil L. The other end of this coil is connected to the grid G of the valve. The filament of the valve is heated by means of a 4-volt accumulator, which may be switched on or off as desired. A half-way connection is taken from the coil L to the positive side of the filament. A variable condenser C is connected across the inductance L. When the circuit is connected up and the filament current switch closed, the whole system will commcommence to oscillate of its own accord at a frequency which may be varied by means of the condenser C. The range of wave-lengths it is desired to measure will determine the size of the inductance L and the capacity C. The lower half of the coil L may be considered a reaction coil coupled to the upper portion which forms the grid oscillatory circuit. The condenser C varies the wave-length of both plate and grid oscillatory circuits at the same time. This arrangement, together with auto-transformer coupling, greatly simplifies the design of the wave-meter without detracting from its efficiency.

In order to calibrate such a wave-meter, an ordinary spark wave-meter of known accuracy is brought near to the instrument and made to transmit waves of known length, which will produce buzzes in the telephones of the oscillating wave-meter when the latter is correctly tuned. The calibration chart of the heterodyning wave-meter is then marked with the readings given by the spark wave-meter. Once such a standard wave-meter has been calibrated, any number of similar wave-meters may be calibrated from it with very great accuracy.

Let us now consider the use of the instrument for measuring continuous waves. Suppose it be brought up to a set which is sending out waves of, say 600 metres length, which is equivalent to a frequency of 500,000 per second. These waves will set up additional oscillations in the circuits of the wave-meter which will have an interference effect on those already taking place. If the wave-meter be adjusted to 550 metres the frequency of the local oscillations will b 545,545. The two sets of oscillations, superimposed on each other, will produce a resultant oscillating current which periodically increases to a maximum amplitude, these "beats" being produced when the two sets of oscillations are momentarily in phase, and therefore assisting each other. The beat-frequency will equal the difference of the two separate frequencies, and will in this case be 45,545.

The valve, in addition to generating oscillations, also acts as a rectifier and will, therefore, rectify any beats produced. The result will be a note in the telephones having a frequency equal to the beat frequency. If this is in excess of about 4,000 nothing will be heard, since the human ear cannot respond well to higher frequencies. If the wave-meter be set to 550 metres, the beat-frequency will be 45,545, which is much too high to be audible. As the wave-meter condenser is turned round to 595 metres, a very high note will be heard which wil gradually get lower as the two frequencies approach each other. When the wave-meter is adjusted to 600 metres, both sets of oscillations will have the same frequency, and, since no beats will be formed, nothing will be heard in the 'phones. As the wave-meter condenser is gradually turned further round to higher wave-lengths this time than 600 metres, beats are once more formed and produce a low note, which gets higher and higher until it dies out at about 605 metres. From this it will be seen that if the wave-meter is more than 55 metres out of adjustment, nothing whatever will be heard, so that great accuracy is attainable. Moreover, the slightest variation of wave length, such as would be caused by putting the hand near the transmitting set, will cause a change of note in the telephones of the wave-meter. On account of this abnormal sensitiveness, it will be found best to enclose the box containing the wave-meter circuits in an outer gauze covering connected to earth.

From the above it will be seen that, in order to measure waves of unknown lengths, it is only necessary to turn the wave-meter condenser round until the note resmbling a "chirp" is hard. When the silent point of this "chirp" is obtained, the wave-meter will register the length of the waves being transmitted. Care should be taken to keep the

(*Concluded on page* 251)

Is Alcohol Dead?

A Discussion of the Necessities and Possibilities of Greatly Increased Future Producing of Fuel Alcohol

J. Paul Heritage, Wharton School of Finance and Commerce

For many years men have been occupied in discussing and discovering substitutes for petroleum. Folks came from afar recently to examine a "great fuel" in green powder and water. Now a real fuel is found and airships will use it, but it costs a dollar a gallon. Despite the various sensations, petroleum products are used and their substitutes chiefly talked about.

The obsequies of the dying petroleum have been more numerous than the farewells of Patti or Harry Lauder. For a long time, investigators have viewed the disappearance of this great fuel with apprehension. However, almost every year has witnessed the discovery of some new field, or process of extraction, by which the yield has been increased. Notwithstanding tax-free industrial alcohol, provided by the Congressional Act of 1907, alcohol production has been disappointing.

One of the first questions to be answered is whether present fuels can supply our needs. The requirements of a motor fuel should be applied against alcohol, considered from a mechanical as well as financial point of view. The possible sources and cost of the product should next be considered.

As to petroleum for the future, it may be expected that new wells and new discoveries will give greater quantities of gasoline for a short period. The Diesel engine may have its counterpart in the automobile of years to come. Kerosene may occupy a larger place than now. The U. S. Geological Survey thinks shale oils can give us fuel for years. The Bureau of Mines urges further campaigns to reduce the waste of gasoline, which has been estimated at 22 per cent. of our production. Prohibition of exportation and use by steam locomotives would aid and save us gallons for the future.

Notwithstanding all of these extensions petroleum must die out. Two factors which indicate this are (1) the life of an oil well is short and many regions have in a brief period become almost exhausted; (2) the tremendously increased demand for the products for the internal-combustion engine indicates their final elimination.

Concerning the first point it may be said that the life of the average oil well is five years.[1] In 1891, the Pennsylvania fields were at their height. In less than twenty years the entire Appalachian field did not produce two-thirds as much as the one state had done. In many districts one out of three wells sunk failed to yield. The Geological Survey has estimated that our supply will last only twenty-seven years at the present rate of consumption. Another estimate places the figure at twenty-two years. Whether we will use heavily of shale oils then, apparently depends on the efficiency and price of alcohol.

Estimates given do not take into consideration the second factor—increasing demand. Automobiles use from 60 to 65 per cent of the gasoline produced. The great growth of machines and trucks is shown by the accompany diagram. The 1919 figure is twelve times as large as that of nine years ago. This growth is almost unparalleled in history and increase of the future looks just as promising. Even in the decade ending three years ago, the machines had increased 600 per cent, while petroleum products has increased only 100 per cent. All of this goes to show that the fossil fuels will be exhausted because of demands on them not anticipated fifteen years ago.

What are the desired qualities of an engine fuel? First of all, it must be mechanically efficient. This would include a host of things, but principally that it should not attack the cylinders, that the explosion should not be too violent, that no residue should be deposited, and if possible, the present form of engine should be retained. The second major requisite is that it should be plentiful—its supply unlimited. The third requisite is that it should be inexpensive, or at least it should compare, if possible, with petroleum in price, when the latter is still further declining in supply. Summarized these desired qualities are,—is it efficient, is it plentiful, is it cheap?

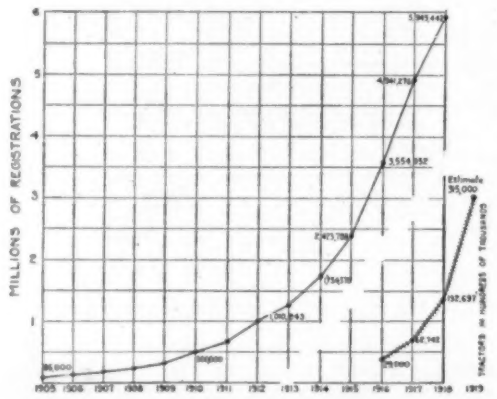
RIVALS OF ALCOHOL

Before taking up alcohol, what of its rivals? Two leaders are benzol and benzine. The former is usually secured from tar, a residue of the by-product coke oven, the latter is secured from gas-house coke. Europe uses these fuels, but chiefly as denaturents for alcohol.

Some mechanical advantages for benzol are (1) ability to ignite easily; (2) absence of "knocking," and (3) of corrosion. Disadvantages are (1) rapid increase of viscosity with the fall of temperature (forming a pasty mass at 8°C.; (2) the olefactory nerve is as sensitive to it as to kerosene. Its price is favorable. Just as the war opened, it sold at 34 cents a gallon in Europe—alcohol and gasoline being 33 and 35 respectively.

A ton of coal will yield one to four gallons of benzol. Assuming the average to be 2½ gallons to the ton, England from its vast production would have secured in a recent year, 30 million gallons. This would have supplied but a small fraction of her needs.

Insufficiency of supply seems to be the greatest objection. We would be worse off in this country because we obtained in 1913 but one-third of our coke by this newer process. During the war herculean efforts were made to boost this reform, yet a recent clipping said that in but one week had by-product coke exceeded bee-hive. Not long ago it was estimated that the benzol to be used would supply but one-tenth of our needs. If we had an engine that could burn any fuel, benzol would be a help, but engines do not change their diet any more easily than people do.



Curves showing, at left, growth of automotive vehicle registration; and, at right, growth of tractor construction.

Benzine is popular with the English. In that country the gas-house gives a million tons of tar and a little over a gallon of benzine can be obtained from each ton. If the benzene is extracted from the coal gas directly, a million tons more could be secured.

The cheapness of this fuel is its main asset. Before the war it sold at 17 cents a gallon. With increased demand its price would probably be much higher. The great disadvantage of benzene is similar to that of benzol—insufficient quantity. They are by-products and therefore dependent for life on the vicissitudes of another industry. While heating by gas is growing, (according to the gas men), they are having competition with electricity for lighting and may soon have it in heating. The possibility of an output ten times the present seems idle even to those who are most likely to talk in terms of prosperity.

EFFICIENCY OF ALCOHOL

Alcohol—is it efficient, plentiful, cheap? Its efficiency was proven here in 1917.[2] The test run from New York to Boston took place in snow. The motors were gasoline cars identical in construction. It was shown that the car using alcohol acted in every way as well as the ones using gasoline and kerosene. It was loaded heavier than the others but showed remarkable pulling qualities, being the nearest like the steam engine.

A questionaire to German farmers concerning the merits of the stationary engine using alcohol developed the following: 4 per cent thought alcohol inferior to steam, 46 per cent thought it of equal worth, and 47 per cent thought alcohol superior. The Geological Survey is conservative, but says, two thousand tests show "that correspondingly well designed alcohol and gasoline engines when running under the most advantageous conditions will consume equal volumes of fuel for which they are designed."

The thermal efficiency for alcohol is not as high as for the other fuels. Alcohol acts slowly but will stand much compression. Gasoline cannot stand a compression of more than fifty to eighty pounds to the square inch. Alcohol is capable of a compression over three times the gasoline minimum. Engineers claim that with a compression of 180 pounds, alcohol will have a 30 per cent advantage over gasoline at 70 pounds pressure. This change would necessitate a somewhat stronger engine, some carburetor adjustment of the intake and possibly nickel construction.

The mechanical advantages of alcohol may be thus summarized:—(1) it is odorless (most other fuels are offensive in this respect); (2) it is less inflammable than most other fuels, but once burning it can be put out with water, which only aggravates gasoline; (3) its freezing point is exceptionally low; (4) it can be used in the present engine, but with some changes, its thermal efficiency will exceed other common fuels; (5) it will have a standard quality the world over. Unlike gasoline, it cannot be easily diluted harmfully. Even the addition of water up to fifty per cent. will not be harmful, although double the quantity will be needed. The motorist, marooned in the country with a teacupful in his tank will appreciate this. With alcohol he will need merely to consult the family pump, the "old oaken bucket" or the babbling brook and start in for an alcohol station.

Difficulty in starting is alleged as a mechanical difficulty, applying to cold weather. A small quantity of gasoline could be carried for this purpose. It is also thought that the installation of an electrical device to heat the alcohol before starting, is not unreasonable.

SOURCES OF ALCOHOL

As to sources, wood appears to have been our chief reliance in the past. Our abundant forests made this country somewhat of a center for the production of alcohol. The output has been insignificant, although the rate of growth has not been. We have done some exporting to Europe in the past and this was, of course, stimulated during the war years.

The Forest Service of Wisconsin, some years ago, determined that twenty gallons of alcohol could be secured from a cord of wood, which cost forty cents. Alcohol then should cost fourteen to twenty cents a gallon. Cordwood in some towns adjacent to woods in the Middle Atlantic States sold for ten times this figure and nearly doubled during the war. The Wisconsin estimate included 60 per cent. waste products on which the chief cost would be transportation. The wood alcohol exported in the years 1914 to 1916, inclusive, sold at forty, forty-seven and fifty-nine cents, and has since been much higher.

European countries have had some experience in this industry. German chemists have found that coniferous varieties of trees produce only about half the alcohol that deciduous varieties do. They have also been unable to secure the charcoal formed as briquettes, which is almost fatal to the industry.[3]

Swedish chemists have been experimenting with wood pulp which they have caused to ferment and produce alcohol. It is significant, however, that these thrifty and industrious people, who have 50 per cent. of their lands in forests, and not a considerable amount of fertile soil, secure 62 per cent. of their alcohol from potatoes, 35 per cent. from maize and grain, and 3 per cent. from beets and molasses. Of course considerable is used for beverages, but not much of the potato product could be so used, as it is obnoxious for this purpose.[4]

[1] W. S. Tower, "The Story of Oil."

[2] Scientific American, Feb. 9, 1907, page 127.

Many of the figures and much of the talk of the possibilities of wood alcohol are based on the utilization of the vast waste material from the forest. Many an industry thrives or fails on whether its by-products are used. It is very doubtful that they could be used on a large scale for the manufacture of wood alcohol. The hardwoods have been considerably exploited. Furthermore, the present centers of this production are in West Virginia, Kentucky, Tennessee and Arkansas, which are not part of our most densely populated area. Hence, transportation would be necessary. Unless we are going to grow trees as we grow plants, we cannot expect rapidly decreasing forests to furnish us material for the great fuel demands of the future. The process of raising trees is infinitely slower than raising plants, and it is to be supposed that man's energies are likely to be directed to those products which mature quickest.

It seems probable alcohol will be secured from starches or sugars because their supply is large and the problem of cost not insuperable. The variety is encyclopedic. The northern clime gives the white potato. Corn is found in both North and South. The sweet potato is principally a southern product, as is cassava. Toward the tropics, sugar, bananas, yams, rice and others might be noted. Starch and sugar products use only sunshine, extracting nothing from the soil, assuming that the slop residue from manufacture into alcohol is fed to cattle and the manure kept on the farm.

Once the raw material is secured the process of manufacture is not difficult. When starch is used it is changed into sugar by the addition of malt. The sugar is then allowed to ferment and the alcohol taken off by repeated distillations. The coming of prohibition will leave many stills without a job. They could be put to use in the manufacture of fuel alcohol and thus save the great cost of installation and economic loss to the brewers.

Our own position with regard to available supply of raw materials is far ahead of the other great users of industrial alcohol in northern Europe. We are adjacent to the tropics, we have one great crop that they cannot grow extensively—corn (maize)—and we have a great variety to select from in case one should fail. This dependence on one crop might prove of vital importance as famine lands have experienced. Those familiar with the importance of the potato in Germany were confident that a blight similar to that in Ireland in 1846 would have ended the war in short order, no matter whether we had American guns at the front or not.

COST OF FUEL ALCOHOL

The argument of experience suggests potatoes as the source of fuel. In Germany, four-fifths of the alcohol produced is made from potatoes.[2] One-tenth of the crop goes into alcohol. Prices before the war ranged from 25 to 40 cents a gallon. The years of lower prices were naturally those of greatest potato yields. In cost comparisons note should be made of the fact that in Germany a large bounty (16 cents a gallon) is given the distiller of alcohol. It is the drinker's treat for the potable article that is taxed for the rebate given the distiller of the industrial brand. The small still is encouraged by an additional rebate and a co-operative society composed particularly of the small distillers backed by the government, regulates prices and exercises control over production.

What chance have we of duplicating the success of Germany? Certainly, we have plenty of poor soil—and the potato thrives on relatively poor soil—sandy loam. Climatic conditions in our North are similar to those in Germany, with the rainfall balance in our favor. Glaciated Wisconsin, Minnesota, and Michigan, it is said could supply all the potatoes now raised in the entire country. None of our centers are realizing their possibilities. The Coastal Plain, from Long Island to Virginia, is a potato area but its acreage in all truck products is said to be but one-fiftieth of the possible.

Will our farmers raise more potatoes? They have a tendency to look at the dollar mark when new crops or greater acreages are mentioned. The bane of the farmer is over-production. This causes low prices. The price fluctuation here has been, in recent years, from about 50 cents to the phenominal 3 dollars per bushel. In Germany the fluctuation for potatoes used for alcohol (as a rule these varieties have more starch and are less edible) varied but 3 cents per bushel (between 19 and 22 cents) during the years 1907-1911, inclusive.

The explanation of this difference is largely found in the fact that the German farmer has several alternatives for his crop. He may sell it for alcohol, for starch, for drying and some would be suitable for table use. In this country he must count on the table only, as the starch factories require but a small amount and the other uses are negligible. Consequently our farmer puts in no more than he feels he can sell in market.

Application of science to raising potatoes would probably show us that we can increase our national average from less than one hundred bushels to fully two hundred, and thus be on a par with England and Germany in yield per acre. The starch content of 10 per cent could be doubled. The way these countries could be left behind on acreage is obvious. The use of spoiling and cull potatoes would be gains over present practices. To supply our power needs we would have to triple or quadruple our present crop. This would not seem impossible on an area fourteen times that of European Germany of 1914.

Corn, a crop distinctly our own, is a rival of the potato as a source of alcohol, but it can be best considered as a companion food of the northern belt. The great thing about corn is its abundance. It could be the author of all our alcohol needs and we would scarcely realize it. One-fifth or one-fourth of our corn crop would supply the substitutes for present gasoline demands, presuming the use of corn stalks. A couple of seasons ago our "biggest ever" crop had quite a frost bite. All this spoiled corn could have been made into alcohol.

Corn and potatoes have the great advantage that they are grown in, or contiguous to sections of our great population. This corresponds roughly to the areas of the largest number of automobile owners. Where this is not the case it would at least represent the potential market. The agricultural belts of the Middle West, as for instance the corn belt, have a high proportion of motors, and, of course, of agricultural power machinery.

The advantage of this concentration of population as well as machines, is in the elimination of the large transportation charge for fuel. The many tank cars and trucks, the expensive pipe lines would in large share be eliminated. The exhaustion of our eastern fields will make the transportation factor a more important one for the future.

In our South, the sweet potato and cassava seem to be rivals. Cassava is a root from which the familiar tapioca is made. The potato has in its favor, at present, the fact that it has more food value than the cassava. Both of these products could be raised in large amounts on the unoccupied lands of the South. Whether they will be raised in abundance depends on how great is the demand for them, and possibly on whether white men can stand the southern climate while engaged in an industry which would require a great deal of hustle. On a price basis, the cassava seems to be better off than its rival, the sweet potato.

As to comparative costs of the vegetable products, it should be noted that most estimates on raw material are based on food prices rather than on raising the products on a new commercial basis. Also the work is experimental and estimates vary because it is difficult to get at actual costs.

If white potatoes sold at 4 dollars a ton, alcohol made from them could probably be sold at thirty-four cents a gallon. This price, however, would be that for cull potatoes, and there would not be a heavy supply of these. With those costing forty-eight cents a bushel (the lowest official price for thirteen years) alcohol would probably cost about seventy-five cents a gallon. The three-dollar raw product would have alcohol higher than diamonds. It has been frequently said by agriculturists that potatoes could be raised in the glaciated areas on cheap lands or in the Spring wheat districts with large scale production on perfectly level areas, for twenty-five cents a bushel. If so, alcohol from this source could probably be obtained for about fifty cents a gallon.

Corn estimates vary from 15 cents a gallon with cobs as the raw material to 45 cents a gallon for corn selling at 70 cents a bushel. Even with the stalks used, potatoes will yield one hundred gallons more alcohol per acre than corn. Potatoes, however, require more work and probably the crop is less certain than corn. Many investigators favor corn over potatoes.

Cassava has a low cost of raw material. Dr. Harvey W. Wiley gives it as 11 cents per gallon if the new acid process is used, otherwise 19 cents would represent the cost. Based on the former figure, the sale price should be about 31 cents. In this, as in the other figures, 10 cents a gallon is added to raw material cost for labor, and 10 for selling and distribution. It is probable that these figures could be reduced after stabilization of costs has taken place, if labor, etc., returns to anywhere near old figures.

Small quantities could be obtained from tropical products, as for instance, molasses waste which sold in Baltimore before the war (1914) at 3 to 5 cents a gallon for raw material. This product could be sold under 25 cents a gallon. Reports from Cuba and China give the very law figure of ten cents per gallon for alcohol.

Consider the great possibilities of the tropics. This is the area where the growth of plants is easiest. Molasses, sugar, bananas, yams or cassava might be secured where their production is so easy. Low prices would be obvious. The transportation charge by water would not be large.

The bad effects of the tropics, however, on white men have been pointed out by Ellsworth Huntington and others. Whether we will be able to get a preponderating share of our alcohol from the tropics depends somewhat on our ability to subjugate them and make them inhabitable for white men, even if his work is to be only managerial. Benjamin Kidd and others have pointed out that we are dependent upon the products of the tropics to a greatly increasing degree. Even so, we could get along without cocoa, coffee, sugar and cocoanuts, but what if the very fabric of our industry depended for most of its fuel on these places? What if the motor truck or farm engine were to depend on whether Gomez or Castro had decided to rule in Venezuela; Huerta, Villa or Carranza to be boss for the fighting season in Mexico, or whether San Domingo decided to have its monthly revolutions once a week.

In fact, Zambo might decide that he wouldn't work at all. Time is no factor in the tropics and the employer does not have the cold and famine slogan with which to threaten his employees when he wants labor performed. The native knows that he can get along just about as easily without work and possibly gets drunk less.

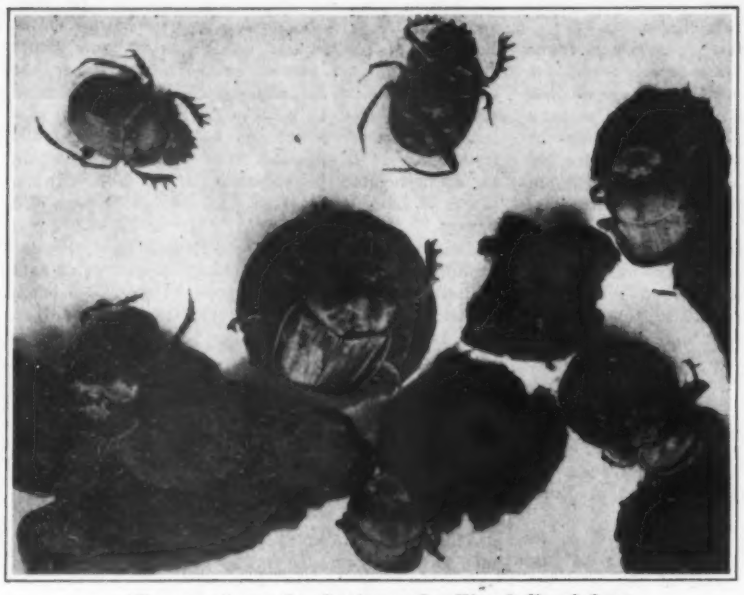
It seems from such surveys as have been made of our agricultural possibilities that there can be no doubt of securing sufficient alcohol for our needs. Summarizing as to sources, it seems likely (1) that because of our great area and abundant variety of products, different sections will use materials for which they are best adapted,—for instance, white potatoes in the industrial East, extreme North and western coast, corn in the Middle West, and probably cassava in the South; (2) each section will also use those products which in a particular year are surplus. This would include the products of a neighboring area which could stand transportation. (3) We cannot omit cheap tropical products, but while we have surplus acres of our own, it is improbable that we will be willing to gamble on the tropics for anywhere near a full supply.

The economic advantages of making alcohol from our own starches and sugars might be summarized as follows:—(1) there will be elimination of farm wastes and the materials will be practically sure of manufacture into alcohol; (2) it will eliminate overproduction and stabilize agricultural prices; (3) it will save transportation charges; (4) it is a perpetual source of power, as far as needs can be foreseen. As land gets scarce, yields will be increased per acre and more lands reclaimed by irrigation or drainage.

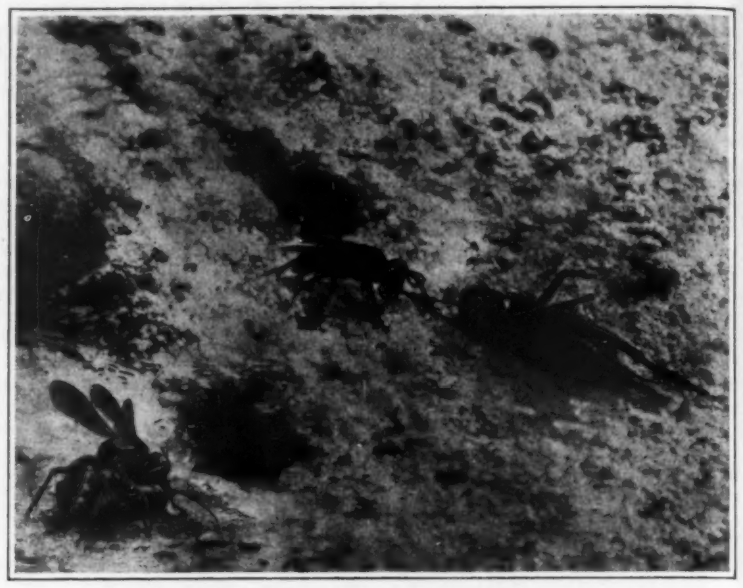
A natural question is, if alcohol is as good as this, why has it not succeeded to a greater extent? It did increase five fold from 1907 (when the encouraging measure passed Congress) to 1913, before the war. In 1916, the total was ten times that of 1913, showing here war influence. Still the total is rather insignificant. Probably the principal reason is that petroleum has held out. Although the price has risen considerably in the decade, yet it is not to the place where we can guarantee an equal figure for alcohol. Many predicted 40-cent gasoline last winter, but it still hovers about 25, and probably it could be reduced or maintained at this figure for considerable time if controlling interests desire. As long as it does so and continues to come in sufficient quantities we will probably not make

(*Concluded on page 256*)

[2]Special Consular Report, 51, page 13.
[3]Special Consular Report, 51, page 18.
[4]U. S. Department of Agriculture, Bulletin No. 182.



The sacred scarabs shaping and rolling balls of dung.



The sphex paralyzing its victim and carrying it off to its den.

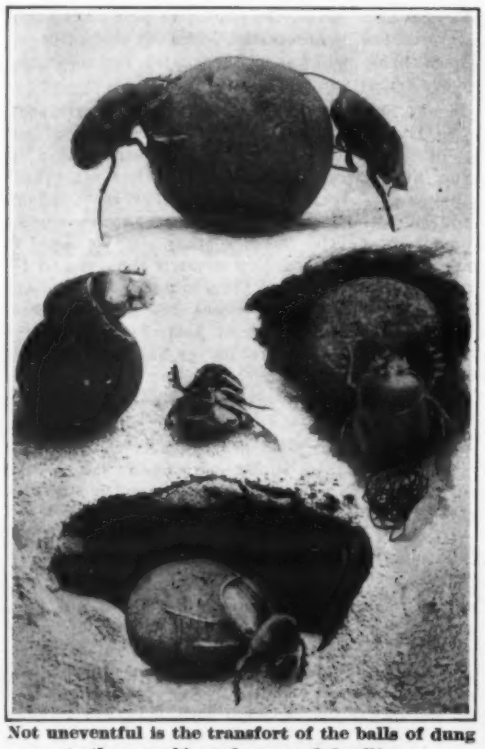
Life Habits of Insects Recorded with the Camera

Fabre's Study of the Scarab

The first volume of the "Souvenirs Entomologique, edition definitive illustree," has just been published in Paris and is thus commented upon by "L'Illustration," to which we are indebted for the accompanying illustrations:

At the beginning of this volume we find the following brief and touching preface: "Broken by old age and deprived of all my means of work by the decline of my forces, the enfeeblement of my sight, and the fact that it is almost impossible for me to move, I feel myself incapable henceforth of adding anything to this work. . . ." Nevertheless, before entirely abandoning his scientific labors, the illustrious entomologist desired to remedy, by the aid of his son, M. Paul Henri Fabre, what he considered to be a lack in the preceding editions of his work. In the volumes of the new series the scenes and the dramatis personae are represented by marvellous photographs. The majority of these were taken from life and represent nature very exactly. In the case of a few of them, however, it was necessary to make actual reconstructions. We have deemed it of interest to lay before our readers some of these documents which have impressed us as being among the most striking. . . .

Scenes of labor or scenes of murder! Let us first watch the insect at work. The sacred scarab, that brilliant insect, that sparkling jewel clad in metal or in ebony, is yoked to his lowly employ of public scavenger. This prince is a scavenger! With the complete set of tools with which nature has endowed him he collects upon the road, then shapes and rolls, his little ball of dung, which was the symbol of the world in ancient Egypt. When he has finished his task the scavenger clasps the sphere with his two long posterior legs, supports himself upon his middle legs and, making use of the toothed brassards of his forelegs, walks backward with his load. Often he is joined by a companion. A neighbor of whom there is indeed no great apparent need leaves his own work and runs to lend a hand. But let us be on our guard! This is merely an attempt at robbery. "The zealous confrère, under the false pretext of giving assistance, cherishes the project of turning the ball aside at the first opportunity. If the proprietor is at all lacking in vigilance his assistant will take to his heels with the treasure; if he is watched too closely for this he will sit down at table with his unwilling host, alleging services rendered. . . ." And besides this sly bandit there is the brutal highwayman to be reckoned with. A bolder scarab takes to his wings and lets himself fall heavily, overwhelming the proprietor, whose position renders him powerless to resist the attack. While the expropriated owner is recovering himself and getting on his legs again, the newcomer intrenches himself on the top of the ball, the most advantageous position for repulsing an assailant. The defrauded owner cannot succeed in regaining possession of his property until he goes to work as a sapper, and undermines the citadel and its garrison. But let us suppose that these untoward incidents have been avoided—the scavenger, continuing to push his ball backwards, reaches a location which he judges to be favorable for the establishment of his burrow. He immediately begins to excavate his refectory by means of his digging tools. When the cavity in the sand has been made ready the provisions are stored away, the sumptuous mass of victuals extending from the floor to the ceiling. When the recluse is once safely lodged together with his provisions he eats. Con-



Not uneventful is the transfort of the balls of dung to the scarab's underground dwellings.

tinuity of the digestive act is proved by an unbroken cord issuing from the anal orifice. . .

But the photograph reveals to us not only these peaceful scenes of the gathering and consumption of provisions, but also scenes of assassination, and allows us to observe the criminal act of a hymenoptera, the sphex, furnishing its burrow with provisions to insure the life of its larva. The problem which confronts the insect is the subterranean storing in a cell of a certain number of pieces of game to suffice for the nourishment of the larva issuing from the egg deposited upon the heap of provisions. Our own game is only too often slain with horrible wounds, but the hymenoptera exhibits an exquisite refinement of cruelty: it desires to leave for its offspring an intact victim having all the freshness of the living insect. But corpses do not appear upon the daily menu of these larvae, these "little ogres which are epicures of fresh meat and which feel an insuperable disgust for game that is the least bit high". However, though the prey is not dead, it must have the appearance of being so. Hence it is necessary to paralyze the insect so as to make it motionless though still alive. There is only one means of achieving this, namely, to wound the nervous apparatus of the victim at one or more skilfully chosen points. This is the procedure of the yellow winged sphex. After having constructed its den it sets forth upon the chase. The game, a cricket, is quickly found, overthrown and pierced by the venomous sting. The prey is immobilized but not dead. The assassin drags its victim by the antennae to the retreat prepared in advance. The sphex then lays its eggs upon the motionless cricket and the larva feeds upon this living flesh throughout its entire larval life.

The accompanying photographs show us other aspects of the chase. This time it is the Languedoc sphex which operates. The chosen victim is not a cricket this time, but a heavy ephippigere, a single piece of game representing an abundant provision of food, and of food very delicately chosen, for the prey pursued and immobilized by the sting is a female, as can be recognized by a sort of sword, the oviscapt, which she bears at the end of the abdomen and which she makes use of in order to bury her eggs in the earth. The larvae of the Languedoc sphex feed upon the eggs of the living but motionless ephippigere in the underground refectory. . . .

As we see, these dramas of the existence of infinitely small creatures exceed in horror all human tragedies. The precise, adroit, and scientific photographs which illustrates these picturesque or atrocious scenes surprised by this man of genius instantly reveal to our eyes the thousand various facts of the life of insects. This is in some sort an illustration of the lessons given from the professor's chair. And this thrilling and unforgetable lesson leads to the development of a philosophic power which impresses us keenly and disturbs us as human beings. The following lines reveal at once the artist, the savant, and the man of thought: "It is the middle of July. This evening the national fête is being celebrated in the village. While the boys and girls gambol around the fireworks of which I catch the reflected gleam upon the church tower, and while the drum celebrates the ascent of each rocket I stand apart and alone in an obscure corner, in the comparative coolness that reigns at nine o'clock, and listen to the concert of the festival of the fields. . . . It is late and the grasshoppers are silent. Sated with light and heat they have

poured forth their symphony all the day. The night brings them rest, but it is a rest which is frequently troubled. From the thick shadow of the plane trees there comes suddenly a cry of anguish, strident and brief. It is the desperate lamentation of the grasshopper surprised in her sleep by the green grasshopper, that ardent nocturnal huntress, which leaps upon her, seizes her by the flank, rips her open and disembowels her. After the musical orgy, the orgy of murder."

In the writings of Fabre there is something both of La Fontaine and of Buffon. This will be perceived more definitely a few centuries hence when so many works which are famous today will have perhaps become only a literary memory, and when the great grand children of our own great grand children will learn to know the life of insects and something of the life of mankind by selections chosen from the thousandth edition of the immortal work of Fabre.

Sex, Reproduction, and Heredity in Pigeons and Fowls.

Dr. Oscar Riddle has previously brought forward evidence to show that male pigeons arise from eggs (yolks) of less storage metabolism, which implies small size and higher (oxidising) metabolism, and that females arise from eggs (yolks) of greater storage metabolism, which implies large size and lower (oxidising) metabolism. He has now (Journ. Exper. Zoology, vol. xxvi., 1918, pp. 227-54) studied two cases of female "identical twins," and seeks to show that the ova (yolks) which produced both of them were extraordinarily and abnormally large.

Of course, the yolk of an egg cannot be directly weighed on a balance and then put back to see what it will develop into; Dr. Riddle's evidence is necessarily indirect. The eggs when laid were very large compared with all the other eggs produced by the particular parents (totals of 116 and 134 eggs). Double-yolked eggs in doves are practically restricted in their production to hybrids from wider crosses, or to birds showing striking reproductive abnormalities, or to both of these, and would not be expected to appear in the series in which the two cases of "identical twins" were found.

It is suggested that the blastoderm-borders will be abnormally raised in extraordinarily large eggs, and abnormally lowered in extraordinarily small ones, and that this might lead, for physical reasons, to the establishment of two independent foci of development. If male "identical twins" were found developing from a very small egg, it would be an interesting corroboration of the author's theory. Meanwhile, he thinks that the available data point to the conclusion that each pair of female "identical twins" arose from a single ovum of high storage metabolism.

In healthy doves and pigeons the right testis is larger than the left in a very high percentage of cases, yet in the female it is the left ovary that persists. The left testis more nearly approaches the ovary than does the right. In disease, particularly in tuberculosis, the testes undergo extreme atrophy, but more in the right than in the left; the ovary does not seem to suffer reduction in size. The right testis of the very young birds (from embryos to squabs a few weeks old) is normally longer than the left. The single (persistent) left ovary of young female squabs is twice, or more than twice, as long as is either testis in males of similar age (three to seven weeks). Now Dr. Riddle finds (Anat. Record, vol. xiv., 1918, pp. 283-334) that in hybrids the normal size relations of the two testes are often disturbed, sometimes reversed, approximating to the female condition. The number of such reversed cases increases as the width of the cross. The excess of males from such crosses is also known to increase similarly, e.g. when the crosses are between members of different genera. The theory suggested is that "sex has been controlled in these forms, and that a male which is forced to arise from a female-producing egg may show in the relative size of its gonads an approximation to the relative size of the gonads of a female."

In an investigation (Journ. Biol. Chem., vol. xxxiv., 1918, pp. 161-70) of the correlation between fat content in the blood of fowls and the total egg records, Dr. Riddle and Mr. J. Arthur Harris find a progressive change; it is positive for birds in a laying condition, sinks to zero after the cessation of laying, and finally takes a high negative value in birds which have long ceased to lay. At the end of the first laying year birds which have laid larger numbers of eggs and are still laying have a higher percentage of fat in their blood than laying birds which have made a poor record for the year. But birds which have laid a large number of eggs and exhausted their fertility have a smaller percentage of fat in their blood than non-laying birds which have poor egg records. Thus the correlation changes from a positive to a negative relationship. This conclusion involves a serious criticism of that reached by Warner and Edmond (Jour, Biol. Chem., vol. xxxi., 1917, p. 281).

Dr. Riddle and Mr. Carl E. Anderson (Amer. Journ. Physiol., vol. xlvii., 1918, pp. 92-102) gave ring-doves small doses of quinine sulphate, and found a marked reduction in the yolk size and total size of the eggs. It is well known that quinine reduces the destruction of nitrogenous components of the tissues, and probably checks the secretory activity of the oviduct, the product (albumen) of which is entirely of a protein nature. Furthermore, the presence of quinine in the yolk of the eggs probably checks the characteristic transformation of the nitrogenous compounds; the eggs are poor in yolk for some weeks after the dosage is discontinued.

From an egg produced by a pigeon under the weakening influence of "reproductive overwork"

The Languedoc sphex, hauling a living bat paralyzed female ephippigere on whose eggs the larvae of the sphex will feed.—Above, at the left, a female ephippigere; at the right, a male.

there was hatched in 1914 a female bird which might be called an ataxic mutation. Dr. Riddle describes the bird (Proc. Soc. Exper. Biol. and Med., vol. xv., 1917, pp. 56-58), which showed when young a marked lack of power over the voluntary movements of the head and body. The affected female was bred to two different males, and the derangement was seen through four generations descended from either. Of 175 young ones reared to the age at which the disorder might be exhibited, 119 were classed as normal and 46 as affected. With some irregularities the character appears like a Mendelian recessive.

In an interesting study of the brains of the "ataxic" pigeons (Amer. Journ. Physiology, vol. xlvii., 1918, pp. 124-36), Miss Mathilda L. Koch and Dr. Riddle report that, as compared with normal birds of the same parentage, there are increased values for moisture, protein, and extracted sulphur, and decreased values for lipoids, phosphatides, and cholesterol. The results of the analyses are interpreted as suggesting a chemical under-differentiation or immaturity of the disordered brains.

Dr. Riddle and Mr. Victor K. La Mer report (Amer. Journ. Physiol., vol. xlvii., 1918, pp. 103-23) a remarkable fact which must be considered in connection with theories of color-inheritance, namely, the post-mortem formation of melanin in the pigment-less retinas and choroids of embryo white ring-doves of 3-12 days of development. Killing the tissues in $HgCl_2$ does not prevent the production of the pigment, but the presence of free oxygen is necessary.—From Nature.

Spontaneous Ignition of Mixtures of Air and Ether Vapor.

E. Allaire, writing in Comptes Rendus, has studied the conditions governing the ignition of air and ether vapor, using a special apparatus by means of which the proportions of the two gases could be varied as desired. The apparatus consisted of a force pump driving air into a gas meter, the measured volume of air passing on into a tube in which it was mixed with ether vapor, obtained by the volatilisation of ether from a tube surrounded by wire electrically heated. The pure ether was measured with a burette. Thus the proportion of ether at 0° and 760 mm. could easily be calculated if the temperature and pressure were known. The gaseous mixture was led into a U-tube, one limb of which was furnished with points like a Vigreux tube and having an opening through which a thermometer could be introduced into the bend. The whole tube was immersed in an oil-bath. Various catalysts, such as oxides of iron, copper, nickel, &c., were tried, but it found that they had apparently no influence on the phenomenon, and the mixture ignited spontaneously at about 190°, when the amount of ether present was about 1 grm. per litre. The flame was pale blue, and visible only in the dark, and the products were ethyl and methyl aldehydes and carbonic and acetic acids. No reaction took place before ignition occurred. A knowledge of this phenomenon explains the occurrence of accidents in factories and workshops in which ether vapor may spread accidentally in large quantities. It might be possible, by modifying the conditions of the experiment and by using tubes of greater diameter, to bring about ignition at lower temperatures.

Acetylene Gas for Welding

Acetylene owes its superiority over some other gases for welding-work to its high carbon content, and to the fact that it is endothermic; that is heat-absorbing in its formation. Energy stored in formation is liberated in the form of heat in dissociation. The combustion of one cubic foot of this gas produces 1,475 heat units. Though theoretically 2½ volumes of oxygen are needed to burn completely one volume of acetylene, the ratio in which the gases need to be employed is one volume of oxygen to one of acetylene, the remainder of the necessary oxygen being taken from the air. In actual practice, this proportion of one to one is approximated to, and the flame yielded by such a mixture is the flame required, the so-called "neutral" flame. By increasing or diminishing the proportion of oxygen, flames known as "oxidising" and "reducing" may be obtained, the appearance of the "cone" changing as the proportions are modified. An oxy-acetylene flame consists of two parts, a small inner luminous cone, bluish-white in color, and a larger enveloping non-luminous flame. The temperature at the apex of the cone is the hottest produced by burning gases and is estimated to be about 6,300°F.—*Engineering and Mining Journal.*

Electric Resistivity of Hardened Steels

Quantitative data and the rate at which the electric resistivity of hardened steel changes when the steel is reheated to a temperature as low as 100° C., and even when standing at ordinary temperatures, are given in a paper by E. D. Campbell, presented before the Iron and Steel Institute in London. A brief summary of this paper follows:

"The steels experimented with contained 0.57, 0.76, 0.945 and 1.05 per cent of carbon, respectively. Bars were heated in an electrical furnace without oxidation to the desired temperature, and quenched in a large volume of water kept below 10° C. by means of crushed ice. After the specific resistance had been measured, one set of bars was placed in an electrically heated drying oven maintained at a temperature between 100° and 108°, and usually between 105° and 108°. They were kept in the oven for three periods of one hour, one period of three hours and one of six hours, their resistance being determined after each period of heating. The total drop in resistance after the 12 hr. tempering was 2.01, 6.50, 9.01 and 10.54 for the four steels. The other set of bars was placed in a cylinder at room temperature, and covered with oil to prevent rusting. Resistance measurements were made at various intervals; and after two years the total drop was found to be 0.47, 2.31, 3.32 and 3.53.—*Iron Age.*

The Langmuir Postulates—II*

An Introduction to Dr. Irving Langmuir's New Theory of the Constitution of Atoms and Molecules

By Ellwood Hendrick

[Concluded from Our Issue of October 11, 1919, Page 212]

NITROGEN AND ITS COMPOUNDS

Nitrogen, atomic number 7, with 7 electrons, cannot be brought into any symmetrical shape by doubling up its atoms to Form N_2. We have the nucleus with its pair, and then five more electrons in its outer shell, which has room for eight, and the five electrons in the outer shell always trying to form an octet. The only symmetrical form in which we can consider two nitrogen atoms to constitute a molecule is to have them slide together into one, with two nuclei in the center, each with a pair of electrons, which accounts for four of the 14 electrons in two atoms of nitrogen, leaving ten over. In the outer shell we have eight, and the remaining two may be held imprisoned within the octet. The arrangement (in a tetragonal form) would be as in Fig. 4. We saw a different kind of double-up in the hydrogen molecule, and it seems that this assumption for N_2 and a few other gases is a happy one.

Nitrogen forms a series of unusual compounds some of which are remarkably active and explosive, and its structure indicates a signal departure in properties from the elements that precede it in atomic number. This single octet with a double kernel is not unique with N_2 although it is unusual. It is the only symmetrical arrangement of certain other bodies, and gives rise to some remarkable comparisons; more particularly of N_2 with CO, and also between these and HCN and NO. Let us compare the N molecule with the CO. The N molecule we have indicated above, with two nuclei, and a total of 14 positive charges, and a pair of electrons about each nucleus, two more imprisoned, and a complete octet in the outer shell. The CO molecule is like it, with its 14 electrons arranged as in N_2, but with the two nuclei differently charged, being one nucleus with a positive charge of six for the carbon and one with eight for oxygen, but also making a total of 14. The outer shells of these two bodies are the same, but their kernels differ. Now let us observe how these two gases resemble each other in physical properties for the very reason that their structures are so much alike.

	CO	N_2
Freezing point in deg. abs.	66	63
Boiling point in deg. abs.	83	78
Critical temperature	122	172
Critical pressure, atmospheres	35	33
Critical volume	5.05	5.17
Solubility in H_2O at 0 deg.C.	3.5	2.46
Density of liquid at boiling point	0.793	0.797
Viscosity, $\pi X10^6$ at 0 deg.C.	163	166

VII

The above is another remarkable example of physical similarity, due to what Dr. Langmuir calls isosterism; to similarity of the molecular structure of the two bodies. But in order to get what follows clearly in mind and to explain why we have pictured the N and CO molecules as tetragonal in shape rather than as spherical, let us enter into further explanation, even at the expense of repetition.

The helium atom with its nucleus and pair of electrons is the type of the innermost shell of every atom; the difference being only in that the nucleus has two positive charges, while the others, except hydrogen, have more positive charges. Since neither electron crosses the equatorial plane, we picture the atom as a nucleus, surrounded by a spherical shell, and each electron as placed within a fixed hemisphere of the shell. There is no reason to feel convinced that the electrons are held in a position of absolute stability, although we must assume that the position of each is circumscribed by the boundaries or walls of its cell. And we can well maintain that its average position is the center of its cell. When two electrons are in a cell we consider them to be placed, as to average position, one above the other, so that when, for instance, two octets are within a shell, we consider these two octets as in layers of eight. Since, according to Postulate I the central shell is divided only by an equatorial plane and the polar axis extending through the second shell and beyond is perpendicular to this equatorial plane, we have in an octet, a symmetry of electrons like that of a tetragonal crystal. Now, having conceived the atom as a sphere, it may seem an undue stretch of the imagination to call it a cube, but from the beginning we have claimed that the positions of the electrons are arranged with tetragonal symmetry. And since from now on we shall deal with electrons as they are arranged in the atoms, and since shells and cells are merely concepts of space, we shall picture every atom containing an octet as cubical in form. The octet is completed, then, when every corner of the cube contains an electron. Shells that contain more than eight electrons contain always multiples of eight cells, if we disregard those that are placed in the polar axis.

*From *Chemical and Metallurgical Engineering.*

Suppose we go back for a minute to the fluorine atom with its nine electrons. There is the nucleus with its pair, and seven corners of the cube engaged. Let's make a working picture of it, Fig. 5. Then another fluorine atom will mate with it to form a molecule, as in Fig. 6. There are 16 corners of the two octets or cubes, all engaged, and each with an electron, but in two places one electron is in a corner of both cubes. The pair of electrons is shared, in other words.

VIII

Now let us develop the theory of octets which forms the basis of what Dr. Langmuir calls **convalency**, to distinguish it from valency in the generally accepted term. We shall not have much trouble here, if we address ourselves to the problem of observing how it works. The main difficulty is that we must take a new point of view, and anything new is likely to be bothersome.

Illustrating "convalency"

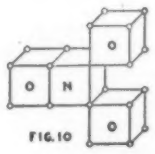


FIG. 10

The Langmuir theory of chemical combination is that these cubical atomic structures want to cover their corners with electrons so as to form complete octets. That is the way they try to complete their octets so as to settle down in life as much as possible like the inert gases, which is the electronic ideal. And we must remember that these cubes do not connect up on their corners. One electron held in common, as in Fig. 7, never holds two atoms together. They connect up either edge to edge, or side to side, so that there is either one pair of electrons, or two pairs, held in common by two combined atoms as in Figs. 8 and 9. It is very rare that the atoms coalesce, as in nitrogen, carbon monoxide, etc., for only under pressure of grim necessity will one atom join with another, making a single cube of two. The rule is as we have stated, either in single or double pairs between two atoms.

DETERMINATION OF CONVALENCY

This is convalency, and Dr. Langmuir has developed the following equation which shows us the necessary structure of the combinations from which we can determine the covalency.

$$e = 8n - 2p$$

or

$$p = \frac{8n - e}{2}$$

in which e is the total number of electrons available in the outer shells of all the atoms of a molecule; n is the number of atoms capable of forming octets, and p is the number of pairs of electrons held in common by the octets. (Postulate VIII.) Another symbol in frequent use is E, which indicates the number of available electrons in the outer shell of an atom. Available electrons means those forming incomplete octets, or, as with hydrogen, incomplete pairs. Thus, for instance, E = 1 for H, Li, Na, etc.; 2 for Be, Mg, etc.; 3 for B; 4 for C and Si; 5 for N and P; 6 for O and S; 7 for the halogens, and zero for the inert gases because the octets are complete and the electrons therefore unavailable.

The equation expresses the fact for every pair of electrons held in common between octets, there is a total of two less—a decrease of two—in the number of electrons contained in the outer shell of all the atoms of a molecule. In other words, two of the electrons, the pair that is held in common by two octets, serve for the same edge in two atoms. This we explained in regard to the fluorine molecule.

CONVALENCY DEFINED

The formation of molecules of compounds, therefore, depends upon the formation of octets, except in the case of hydrogen, of which the ion (which is the nucleus of this element) takes its place between two electrons. *Then the convalency of an atom is the number of pairs of electrons that it shares with adjacent* atoms. We shall soon see that convalency is not the same as valency although convalency is in full accord with the valency theory in connection with organic compounds wherever formulas are written with carbon having a valency of 4; nitrogen 3; oxygen 2; hydrogen 1. But when it has been necessary to assume a valency of 5 for nitrogen and phosphorus; 4 or 6 for sulphur; 3, 5 or 7 for chlorine, then it gives results totally different, but in better agreement with the facts.

We can get a better idea, however, of the working of convalency by applying the rule. Let us use as our example a familiar salt, $NaNO_3$. Repeating the equation $p = \frac{8n - e}{2}$ we have one electron available from Na which has the atomic number 11, and is therefore like neon, but with one more electron which is available in the outer shell; 5 for the nitrogen atom as we have already explained (N having atomic number 7 and so having 5 in the shell outside of its nucleus and pair) and 3 times 6, or 18, for O_3. So: $e = 1 + 5 + 18$, or 24. There are 24 available electrons in all the atoms of the compound. Then n, or the number of atoms capable of forming octets, would be 1 for nitrogen and 3 for O_3. Sodium with its one lone electron in the outer shell will give it up rather than gather on seven more, so Na is incapable of forming an octet. Therefore $n = 1 + 3$, or 4. Then $p = \frac{8n - e}{2}$ or $\frac{(8 \times 4) - 24}{2}$ or $\frac{8}{2}$ or 4. Now let's make a picture of it in Fig. 10.

THE PLAY OF ELECTROSTATIC FORCE

Hence we have two octets complete, with four pairs, held by octets in common. It provides for our NO_3 and it took an electron from the Na atom to do it, leaving the Na ion out in the cold; the Na ion being, of course, the Na atom with its one available electron extracted. But since the Na ion is positively charged we do not need any inexplicable valency to hold it on; it will stick on of itself.

The Na ion is positive because it has lost an electron which has wandered over to complete the octets in NO_3. The Na nucleus has 11 positive charges and this ion has but 10 electrons, so it must be positive. Conversely, the NO_3 ion is a negative, because its atoms, originally electrically neutral, have taken up the extra electron from the sodium atom. To make this abundantly clear let us note that the total positive charges on the nuclei of NO_3 (7 for N, and 3×8 for O_3) are 31, while there are 32 electrons in the ion: 24 in the shells and 8 altogether in the 4 kernels. It must be negative, therefore, with 31 positive charges and 32 electrons negatively charged. So with an opposing charge for each of the two ions, positive for that of sodium and negative for NO_3, we have no need of other valency. The electrostatic

force will hold all the positive and negative ions together, not in molecules, but built into a lattice of the entire mass, in alternate fashion, each Na ion attracting all the NO_3 ions about it, and vice versa. They do not produce molecules; they produce balanced Na + and NO_3—ions, held together by electrostatic force.

When $NaNO_3$ is molten it becomes an electrolytic conductor, because under the influence of an electric field its ions are able to move. In solid $NaNO_3$, the ions already exist, and when it is brought into contact with water the high dielectric, constant of this weakens the electric field which holds the ions together, allowing them to separate, which accounts for the ready solubility of the $NaNO_3$ in water. And, dissolved in water, it is, of course, a good electrolytic conductor because the ions are already separated from one another.

It is interesting to note that only within the past year three remarkable papers have appeared, by Milner in England, Ghosh in India, and Bjerrum in Germany, showing from different viewpoints and from independent work that strong electrolytes are completely ionized, even in a strong solution. The octet theory leads inevitably to the above conclusion, and apparent discrepancies in the law of mass action are thus accounted for. The same method of argument applies to all salt-like substances, and in all these salts the covalency of the metal ions is zero. They do not form molecules because their ions are held together by electrostatic force and not by convalency, that is, by the sharing of pairs of electrons between them.

IX

The theory of convalency becomes simple with practice, although it lacks the *ipse dixit* quality of the valence theory. It cannot be learned by heart; in every instance it has to be reasoned out, but by the aid of the octet equation the complete picture may be rapidly visualized. We have already stated that it is in full accord with, or is the exact equivalent of, the valence theory in connection with organic compounds when the formulas are written with a valency of 4 for carbon; 3 for nitrogen; 2 for oxygen, and 1 for hydrogen, but that the results differ when it is necessary to assume a valency of 5 for nitrogen and phosphorus, 4 or 6 for sulphur; 3, 5 or 7 for chlorine. These will be explained in future papers by Dr. Langmuir, in which such compounds as those of phosphonium, sulphonium, oxonium, diazonium, etc., are particularly well accounted for. The method of application, however, is somewhat similar to that of ammonium, which we shall now consider. In the meantime we must bear in mind that 4 is the highest convalency an atom can possibly have, because no atom can engage itself with one or more others by sharing over 4 pairs to form an octet.

In NH_4Cl the octet rule shows that p (or pairs of atoms held in common) $= \frac{8n - e}{2}$ in which n (the number of atoms capable of forming octets, being Cl and N but not H) is 2, and e (or total number of all the electrons available in all the atoms) is 7 for Cl, 5 for N, and 4 for H_4, or 16. So we have $p = \frac{16 - 16}{2}$ or 0, so that the N and Cl atoms have no pairs in common, although each is capable of forming octets. Then the hydrogen nuclei, being positively charged because they have each lost one electron, will tend to dispose themselves, each one between two electrons on the nitrogen octet. Their electrons have gone; one to complete the chlorine octet and the remaining three to do this same with the nitrogen atom. Now these hydrogen ions can also distribute themselves, one to the chlorine atom and three to nitrogen to produce HCl and NH_4, but by attaching themselves each to the four pairs of electrons on the nitrogen ion there is achieved a greater symmetry, and the hydrogen ions will do this until the temperature is so increased as to drive the nitrogen and chlorine ions apart from each other. Then one of the hydrogen ions, having its electron taken by chlorine, will follow it, and pair off with it between two electrons, giving us NH_3 and HCl. But with ammonium chloride we have as its two parts NH_4 and Cl. The ammonium ion is positive for the obvious reason that, with five nuclei, there are 11 positive charges, 7 for nitrogen and 4 for H_4, and only 10 electrons negatively charged to match them. On the other hand, the Cl ion carries in its complete octet one more electron (taken from a hydrogen atom) than the number of positive charges on its nucleus, and therefore it is negative. The equation taught us that the number of pairs shared by octets was 0. Ammonium chloride therefore is a salt, the ions NH_4 and Cl are held together by electrostatic force, and so it does not form molecules; in solution the ions become separated, and therefore it is an electrolytic conductor.

We observe from this nitrogen cube with an electron at every corner, and hydrogen ion held by every pair of electrons, that NH_5 is impossible. It also indicates why NCl_5 does not exist. NH_4 is an ion, and not a compound because it contains one hydrogen nucleus that lacks its electron, which in this case went over to the chlorine atom. There is nothing to indicate a valency of 5 for nitrogen in the octet theory.

SIMILARITY OF AMMONIUM AND POSTASSIUM COMPOUNDS

A curious feature of the NH_4 ion is that it is surprisingly like the CH_4 molecule. They have the same number of electrons, the same structure, and they differ only in the electric charges of their respective nuclei. The hydrogen ions are held in the same way; both carbon and nitrogen forming complete octets, and both have a hydrogen ion for every respective pair of electrons in the outer shell. Let us note at this point that the potassium ion—the potassium atom with one electron taken from it—is similar in structure to the argon atom except for the fact that the argon nucleus carries 18 positive charges and the potassium nucleus 19. Argon and CH_4 are very similar in their boiling points, etc. The fields of force of Ar and CH_4 are very similar, and the potassium ion differs from Ar just as the NH_4 ion differs from CH_4. Now things that differ equally from similar things are similar to one another, and it stands to reason that the K ion and NH_4 ion are as closely related to each other as are argon and methane. Therefore the K and NH_4 salts should be similar. And they are with remarkable frequency isomorphous in their crystal forms, and similar in their solubility and other physical characteristics.

X

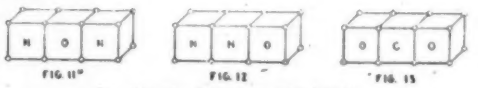


FIG. 11. FIG. 12. FIG. 13.

Illustrating "isosterism"

The same argument may be used to show that the NH_4 ion resembles the K ion much more closely than it does that of Na, since the Na ion has a structure like that of neon, in that it differs from it only in the electric charge of its nucleus, Ne being 10 and Na 11. Since neon does not resemble CH_4 as closely as does argon, it follows that the Na ion does not resemble the NH_4 ion as closely as does that of K, and the conclusion is amply supported by the physical characteristics of their respective salts.

X

Isosterism. We have already considered pairs of substances which when found to be closely related to each other in their several structures, prove to have remarkable relationships. When two substances have the same number and arrangement of electrons they are said to be isosteric. N_2 and CO are examples and show isosteric resemblances. If, then, besides the isosteric quality they have the same total number of positive charges in their kernels (or in all the nuclei in the molecule) then we shall expect the external field of force to be approximately the same in both cases, leading to approximate identity in physical properties. If the nuclei differ in their total charge, then one of the isosters may be electrically charged when the other is not, so that the forces around the respective molecules become very different; then most of their properties will also differ.

RELATIONSHIPS OF ISOSTERS

This subject of isosterism abounds in evidences of the reasonableness of the Langmuir postulates and we find that closely related structures show closely related physical relationships, so that we can even trace them beyond the isosters. We have noted the similarity of structure of CO and N_2 molecules, which are true isosters. We have seen that because of the isosterism of CH_4 and NH_4 + and that of Ar and K + and from the similarity of CH_4 and Ar, it follows that NH_4 + and K + are similar, although not isosteric. We cannot compare atoms with ions, but we may reason that if Ar resembles CH_4 then an ion that is isosteric with argon will also resemble another ion that is isosteric with CH_4.

If two substances, besides being isosters in having the same number and arrangement of their electrons, have also the same number of positive charges on the nuclei of all their atoms, then we have a right to expect the external field of force to be approximately the same in both cases, and that they will have approximately identical physical properties. On the other hand, if the positive electric charges on the nuclei of the atoms of two or more isosteric substances differ, then the forces around the respective molecules will differ, and most of their physical properties will differ. Thus the potassium ion and the argon atom, although isosteric, are differently charged, and we find them totally different in their physical and chemical properties. But we can make use of their analogies to other bodies, and thus trace out relationships which are of great aid in indicating the probable nature of their substances.

We shall give a number of instances of isosteric substances with observations made by Dr. Langmuir which will form parts of articles to appear later in the **Journal** of the American Chemical Society.

We gave early in this paper the coincidence of figures in relation to the properties of N_2O and and CO_2. Now we can undertake to give the reason for them. The octet rule shows p = 4 for both. So we have three cubes—three blocks, let us say—to be put together so they have four pairs of electrons or edges jointly. The simpest form would be three in a row, and we have N-N-O as in Figs. 11 and 12. And we have convalences—in this case, 4 for O and 2 for N; or 4 for one N and 2 for the other N, and 2 for O. CO_2 must be O-C-O, Fig. 13, and we then have $\overset{7+}{N}\ \overset{8+}{O}\ \overset{7+}{N}$ or 22 positive charges on the 3 nuclei. With CO_2 we have $\overset{8+}{O}\ \overset{6+}{C}\ \overset{8+}{O}$ also 22 positive charges on the nuclei of its 3 atoms. There are 24 corners to the three cubes, but as 4 pairs of electrons are held in common we need 24—8 electrons, or 16 electrons, in the outer shell of each molecule—and there they are!

Let us cite a few other examples, more particularly with reference to the crystal forms: ClO_4—, SO_4— and PO_4———. These are isosteric, therefore we should find similarities in the crystals of their salts. Investigation brings out the following: $CaHPO_4$ and $NaHSO_4$ crystallize in triclinic pinacoids, showing the following axes and angles of their axes:

	a	b	c	a	b	c
$CaHPO_4$	...0.6467	1	0.8244	84°57′	89°43′	85°38′
$NaHSO_4$	...0.646	1	0.837	85°06′	88°57′	86°47′

or almost wholly within the limit of experimental error, notwithstanding the marked difference in solubilities and similar physical properties.

These observations infuse life into Groth's otherwise dreary *Chemische Krystallographie*.

Again, $KClO_4$ and $SrSO_4$ are isosteric; they belong to the orthorhombic system, and show the following ratios of their axes:

	a	b	c
$KClO_4$	0.7817	1	1.2798
$SrSO_4$	0.7790	1	1.2802

Double refraction is positive in both and they show the same cleavages. They are, as are the others, typical cases of isomorphism, and thus afford direct experimental proof that $KClO_4$ and $SrSO_4$ have similar constitutions. The octet theory indicates that the central atom in both compounds has a covalency of 4. The usual viewpoint of the chemist is that the valency of Cl in $KClO_4$ is 7, while that of sulphur in $SrSO_4$ is 6. But the fact that these compounds are isomorphous encourages the belief that the rutinary theory with valencies of 7 for Cl and 6 for S is wrong.

ISOTERIC NATURE OF APPARENTLY UNRELATED COMPOUNDS

Here follow more preliminary notes, to be dealt with in detail later by Dr. Langmuir:

$SrHPO_4$ and $KHSO_4$ are orthorhombic-pyramidal in form; their angles of axes are:

	a	b	c
$SrHPO_4$	0.8607	1	1.9344
$KHSO_4$	0.8581	1	1.9431

The optical axis in each is in (001) plane, and the habitus of the crystal forms are practically identical.

NaF and MgO are isosteric and are isomorphous in their crystal structures, according to measurements recently made by the X-ray method by Dr. Hull.

(*Concluded on page 251*)

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Texas oil cities that sprang up "over night."—At the left the city of Ranger, at the right a residence street in Burkburnett.

The Rotary Method of Well Drilling*

Combining Rotary and Cable-tool Methods in Alternating Soft and Hard Formations

By Albert G. Wolf, Mining Engineer

It has been stated that rotary well drilling was invented in 1845. If so, its early development was slow, for the first oil well in this country was drilled by the percussion method in 1859, by Colonel E. L. Drake, at Titusville, Pa. In 1888, however, the rotary method was employed in a crude way in the Gulf Coast country. Two strings of pipe were used, the one to rotate the drill, and the other to wall up or case the hole as it progressed. During the next year it was discovered that thick mud, the more plastic the better, pumped into the hole through the drill stem, would support the walls until the drilling was finished, if the hole was not too deep, thus allowing the casing to be set afterward in one operation. The discovery, credited to B. Andrews, Sr., of New Orleans, La., is the most important in the development of the rotary method. From this time the process was further developed and improved in the oil fields of Louisiana and Texas, where, it is stated, in ten years more than 10,000 wells were successfully completed in formations in which it was impossible to drill and maintain a hole by any other system.

In 1900, Captain J. F. Lucas began drilling at Spindletop, near Beaumont, Tex., with a rotary rig, and in January, 1901, he brought in the first oil gusher drilled by the rotary method. This was after repeated failures had been made with cable- and pole-tool rigs. It may be, too, that the combination method was first used here, for I am informed that after this success the softer formations were drilled with rotary machines, and the hard cap-rock was penetrated by cable-tool rigs.

Another discovery of importance, and one which really made the rotary method a serious competitor of the cable-tool system in moderately hard rock, was that of the Hughes rotary rock bit. The bit was invented by Howard R. Hughes, and its manufacture started in 1909 at Houston, Tex. No other rotary bit is so effective in the harder strata, and its invention has assured the adaptability of the rotary method of drilling in fields where other than soft strata occur. In the years 1905, 1906, and 1907 its use spread all over the world, and during this period it was introduced into California. Here the requirements for drilling considerably deeper wells than the average depth in Louisiana and Texas necessitated the design and construction of heavier machines.

Each succeeding year has brought new improvements and a gradual development of still heavier machines, until now the weight of the rotary on the heaviest machines, for example, has increased nearly four-fold over that of the one used by Mr. Andrews in 1888. Even larger machines, it is thought, may be manufactured.

In the rotary method of drilling, the bit is suspended by means of a string of pipe called the "drill stem," and the bit and drill stem are rotated by the "rotary" in the center of the derrick floor. The drill stem varies in size, depending on the diameter of the hole being drilled, and is made of wrought iron and steel. The rotary turntable is revolved by a gear wheel underneath, keyed to the rotary shaft, the shaft being driven by sprocket-and-chain drive from the draw-works line shaft, which, in turn, is also driven by sprocket and chain, from the engine crankshaft.

The drill stem is suspended while drilling, or when it is being raised or lowered, by a cable, passing from a drum on the drumshaft of the draw-works up over the sheaves of the crown block, on the top of the derrick, and down through the traveling block. This block system of suspension is necessary to make possible handling with ease and accuracy the great weight of a string of drill stem in a deep hole. The drumshaft is driven from the lineshaft by sprockets and chains, two sets of gears being provided for two speeds. The lowering is controlled by a brake on the drumshaft.

Either one or two brake bands are provided. From the traveling block is suspended the C-hook, which

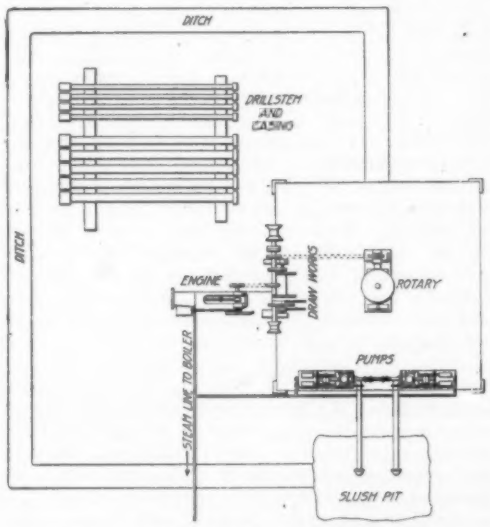


Fig. 1. Plan of a Rotary Drilling Rig.

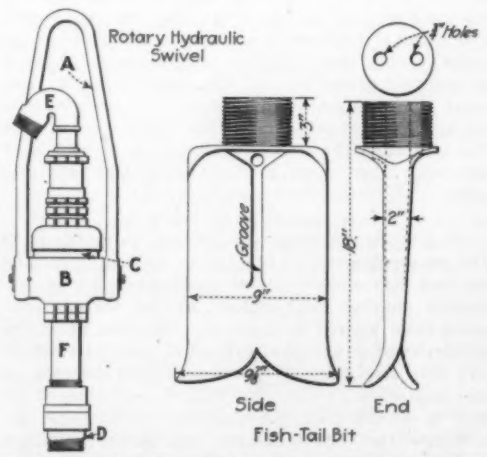


Fig. 2. Hydraulic swivel used in the rotary method and a fish-tail bit.

in turn engages the bail of the swivel. Upon the swivel is screwed the "grief stem," "groove stem" or "Kelly joint" (the latter being the drillers' field name for it), and this is screwed into the top joint of the drill stem. The grief stem is gripped in the rotary table by a special bushing or by a set of grip rings. By the use of the latter the grief stem can be dispensed with, the grip rings taking hold directly on the drill stem. This, however, results in the serious scarring and denting of the pipe, and, too, the grip rings are more inconvenient than the grief stem with bushing, and consume more time in the operations.

When raising or lowering the drill stem, the grief stem, with swivel attached, is unscrewed from the drill stem, and the latter is suspended by means of "elevators" which hang from the C-hook. While unscrewing a joint of drill stem, or two, three or four joints together, as the case may be (the words drill stem and drill pipe being used interchangeably), the stem in the hole is held by the "slips" in the rotary until the unscrewed length is set aside and the elevators are re-attached to the drill stem. The slips, it should be added, are triangular-shaped pieces of iron with corrugated steel faces, which wedge in between the drill stem and the rotary table. The driller stands at the right of the draw-works, facing the rotary, and controls all the operations, having at hand the brake lever, two levers for operating the two drum clutches, rotary drive-clutch lever, steam throttle, and engine reverse gear.

The swivel is so constructed that it will not only allow the drill pipe to revolve but will support the entire weight of the string of tools, permitting the drill stem to be raised or lowered while revolving. At the top of the swivel is a gooseneck, connected with the manifold between the pumps by means of a wire-wound hose. Through this connection and down through the swivel and grief stem, both being hollow, water or liquid mud is pumped. This passes down through the drill stem, out through two holes in the bit, and up the outside of the drill stem, carrying with it the cuttings. Another purpose served by the mud pumped into the hole, which gives the rotary system its great advantage over the cable-tool method in loose ground, is that of sealing up the crumbling walls of the well in an unconsolidated formation.

In the general plan of a rotary drilling outfit, (Fig. 1, page 250), the derrick is centered over the well location and the rotary is placed at about the center of the derrick floor, on a firm foundation of large timbers, with the center of the rotary table over the location point of the well. The draw-works are erected on one side of the derrick, with the engine, on a timber foundation, immediately back of them, outside the derrick floor.

The driller stands at the right side of the draw-works, facing the rotary; and the pumps, two in number, are placed on the side of the derrick floor to his right, at the edge of the floor. The pumps are duplex, and are placed end-on, with water cylinders facing. The discharges are connected by a manifold, which permits the operation of either pump. This is to make it possible to repair one pump while the other is in operation. The suctions

*From *The Engineering and Mining Journal.*

of the pumps are connected with the "slush pit" by suction pipes fitted with foot valves and strainers at their lower ends.

A ditch leads from the well, out on the opposite side of the derrick from the pit, surrounds half the derrick, usually on the engine side, and leads back to the slush pit. This arrangement returns the water or mud to the pit, thus conserving it; prevents its overflow upon adjacent lands, and gives its sand or shell cuttings a chance to settle out in the ditch before reaching the pit, for it is not desirable to pump sand or shell into the well.

On the opposite side of the derrick from the draw-works are piled the extra lengths of drill stem and casing, all parallel with each other, and with collar ends pointing toward the derrick, for convenience in pulling upon the derrick floor and hoisting into position. On this side of the derrick, up to the top of the second bent, the center one-third of the girts and braces is cut out and the ends are joined together, leaving a high opening through which the lengths of drill stem and casings are raised and lowered as required.

The boiler is placed at any convenient distance from the rig, say 50 or 100 ft., unless natural gas in quantity is opened, when it is moved back a considerable distance to avoid the danger of fire. Usually the boiler is housed more or less roughly, according to the rigor of the climate, to conserve fuel. Fuel oil is the most commonly used fuel.

In adding to the drill stem already in the well the procedure is as follows: The string is pulled up until the lower end of the grief stem is three or four feet above the rotary, and this joint is then unscrewed. The grief stem and swivel together are then swung to one side, and the stem is lowered into a 20 or 30-ft. hole, already drilled and cased for this purpose, called the "rat hole." The bail of the swivel is released from the C-hook, and a pair of elevators of the correct size for the drill pipe substituted. A length of drill stem is pushed up on the derrick floor, the elevators are clamped around it just below the collar, and the length of stem is swung into a vertical position just high enough for its lower end to clear the collar of the drill pipe held in the rotary. Some "dope" is put on the threads, and the new length lowered and screwed on. The entire string of drill stem is then lowered until the new piece has taken the previous place of the next lower one; the grief stem, with swivel attached, is replaced and lowered; the pump is started, and drilling resumed.

When a bit becomes dull, all the drill stem must be removed from the hole. The drill stem is hoisted and unscrewed, "broken down," in sections of one, two, three, or four pieces (called "singles," "doublets," "triplets," and "fourbles" by the crew) as the case may require and the height of the derrick permit, and set on one side of the derrick floor, standing up in the derrick. This unscrewing can be done either by hand, using chain tongs or patented tongs, or by means of the rotary and special tongs, the latter a much easier and more expeditious method.

Derrick for rotary drilling 86 feet high.

PARTS OF DRILLING RIG

Engine — Drilling-rig engines are usually of the single-cylinder type, in cylinder sizes from 8 by 12 in., of 12 hp., to 12 by 16 in., of 30 hp. There are some as large as 16 by in., of 70 hp., but they are exceptional, as is the use of more than a single cylinder engine. For rotary work the engines differ from those of a sprocket for the belt pulley on the crankshaft.

Draw-Works — The draw-works consist of two parallel shafts, the drum and the lineshaft. On the drum-shaft are the hoisting drum, either one or two brake bands, two sprockets, and two clutches for the two hoisting speeds. The lineshaft is above and a little behind the drumshaft, and on it are usually four sprockets, one for receiving the drive from the engine, two sprockets for driving the drumshaft at different speeds (called drum-drive and quick-hoist sprockets), and the rotary-drive sprocket. Sometimes a fifth sprocket is added to drive a mud mixer. In addition, there are two cat heads or winch heads, one at either end of the shaft. The drumshaft diameter varies with the size of the rig, 5 in. and 6 in. being used for the largest rigs, and approximately 4, 4½, and 5 in. for the smaller single brakeband draw-works. Lineshafts are approximately of 3⅜ to 3¾ in. diameter, and 11 to 12 ft. long. The total weight of the draw-works varies from about 6,000 lb. to 9,500 lb., and sometimes reaches 11,000 lb. in extra heavy draw-works for export.

Rotary—The rotary consists of a circular table of semi-steel, called the table, turntable or gear table, resting on cone bearings, and under all a heavy cast-iron foundation resting on two skids. The table is driven from below by a pinion, the latter keyed to a shaft and driven by sprocket and chain from the draw-works. By means of a clutch between the sprocket and pinion the table can be thrown in and out of gear with the line-shaft, making it possible to turn the table around by hand when necessary. In the center of the table there is a circular opening through which the tools and pipe are passed, and into which fit the slips for holding the pipe when adding or removing joints or the bushing to hold the grief stem when drilling. When drilling with grip rings, this device rests on the table, with driving posts projecting down into holes in the table top.

Modern rotaries vary in size from 14 to 26 in., the number signifying the width of the largest size bit that will pass through the central opening. The largest size pipe is two inches less. In weight, corresponding to these sizes, they vary from 2,500 to 7,800 lb. complete, or 1,650 to 4,500 lb. without the grip-ring device. These sizes and dimensions are, of course, general, as they vary somewhat with different makes. The diameters of the tables corresponding to these sizes are from 38 to 58 in. Mechanical improvements have been made in rotaries during the last few years, the more important including cone bearings instead of open ones; a better oiling system, and the use of higher-grade materials throughout.

Pumps—The slush pumps used with the rotary rig are two in number, so that one can be in operation while the other is being repacked or repaired, as the wear and tear on the pumps is heavy. The type of pump is a duplex, steam driven, varying in size from 6 by 4 by 6 in. to 13 by 7 by 14 in. The 10 by 5¾ by 12 in. size is a common one in use. Corresponding weights vary from 550 lb. for the smallest size, rarely used, to 7,100 lb. for the largest. The pumps are designed to operate against a high pressure, and have removable water-cylinder liners. Some also have changeable packing and metal valves on the water end.

Boiler—Horizontal, fire-tube boilers are generally used, and range from 20 to 50 hp., although for anything except the shallowest of holes less than 40 hp. is not serviceable. Corresponding heating surfaces are 276 to 620 sq.ft. Pressure rating is usually 100 lb., 125 lb., or 150 lb. Fuel oil or crude oil, wherever available, is the most commonly used fuel, and has several advantages over other fuels. Gas is also used to good advantage. Some of the boilers are mounted on trucks for portability, but with the larger-sized boilers these carriages break down, and are not an advantage. The boilers weigh from 5,700 lb. in the light 20-hp. size to 11,500 lb. for a 50-hp. boiler.

Derrick—The derricks for rotary drilling are not different from those used in cable-tool work. In height they vary from 66 to 130 ft., and in spread from 18 to 28 ft. The height used depends somewhat on the depth of the well to be drilled, although sometimes its size may be limited by the size of the tract of land controlled. The shorter derricks are for shallow holes, and necessitate breaking down the drill stem in doubles (two joints together). For work up to 1,200 ft., an 86-ft. derricks is sufficient, allowing lengths of three joints to be hoisted. For deeper work the higher derricks are used, although the 112-ft. derrick is sufficiently high for all but the deepest work. Derricks are built of either wood or steel, the former being by far the more common and preferred.

The building of derricks is a special branch of the carpenter's trade, and usually there are men in the field who will contract to do this work, and it usually pays to employ the contractor, for the construction of a derrick with labor unfamiliar with the work is a slow and costly job. The following is a list of contract prices for building derricks in a southeastern Texas field, the prices being for labor only, including doubling the

(1) Rotary in foreground; draw-works in rear; driller at his station. (2) Rear view of engine and draw works. (3) Rotary in center, drill stem standing in derrick. (4) Boiler housing in gulf coast country.

Rotary well-drilling machinery.

legs and putting on double guy wires:

Size of Derrick, Ft.	Cost	Size of Derrick, Ft.	Cost
64	$75.00	85	$90.00
74	80.00	90	95.00
82	85.00	112	150.00

Derricks are usually torn down by contract also, and in this work it pays to employ skilled labor because of the greater saving of material.

Crown Block—Crown blocks are made of wood, either hard or soft, or steel I-beams, and steel pulleys. The principal members, four in number, are arranged parallel to each other, and are held apart by spacking blocks. The I-beams are 8, 10 or 12 in. high. The pulleys, five in number for rotary work, run vertically between these main members, and are arranged like the five-spots on a playing card. Pulley sizes vary, a diameter of 22 in. being common. The steel crown block is an improvement on the older wooden crown block.

Swivel—The rotary hydraulic swivel is so constructed that it can support the entire weight of the string, permit the stem to revolve, and allow water or mud to be pumped down through it under high pressure without leaking. Fig. 2 shows one form of swivel in use. It is suspended from the C-hook under the traveling block by the bail A, and this, in turn, supports the trunion B.

On the trunnion is placed the bearing race (designed for ball or cone bearings in different makes), bearings (inside at C, Fig. 2), and bearing seat. The bearings at this point must sustain the entire weight of the drill stem. Water or mud from the slush pit is pumped into the gooseneck E, from which it passes down through the standpipe F, into the grief stem at its point of connection D, and so into the drill stem.

The swivel is tightly held together by various lock collars, permitting the revolution of the standpipe, yet making a water-tight connection with the gooseneck, which, being connected to the hose from the manifold, cannot revolve. Swivels range in size from 3 to 6 in., the number indicating the size of the pipe connection at D. A 3-in. swivel weighs from 300 to 400 lb., a 4-in. swivel from 600 to 700 lb., a 5-in. swivel from 850 to 1,200 lb., and a 6-in. from 1,350 to 1,800 lb.

Bits—The "fish-tail" bit, also shown in Fig. 2, is especially designed for rotary drilling, and though other shapes are used, it is the type most generally employed. It is made of common steel or some of the alloyed steels, but must not be brittle. All sizes, from 4- to 24-in. bits, measured across from tip to tip, can be readily procured, and smaller or larger ones may be had on special order. All dimensions vary with the width of the bit except the shank diameter, which is usually made in three or four standard sizes, for 2½-, 3-, 4-, and 6-in. pipe fittings, the largest bits being obtainable only with the largest-sized shank. Shanks are also made either straight, for pipe collars, or tapered, for special tool-joint connectors.

As a bit is revolved in the well, the two fins, or cutting edges, wear against the formation, cutting it like an auger. Water or mud pumped down through the drill stem passes out through the two holes in the bit, washing the cuttings aside and carrying them up with the current. At intervals of greater or less duration, depending on the hardness of the strata, the bit must be withdrawn from the well, sharpened and tempered. The tempering is of great importance, for on it depends to a large extent the speed of drilling. If the temper is too soft, frequent changes of bits will be necessary, and, if too hard, the bit will break. If the latter should happen in a hard stratum, considerable time will be lost in "wearing out" the piece of steel. Other shapes of bits sometimes used are the diamond point and the drag bit, which somewhat resembles the bottom end of a wood auger.

In hard rock the rotary rock bits, referred to previously, are most successful. These bits have two hard-steel cones on the lower end, each cone on a shaft, leaving them free to revolve separately. The conical surfaces are corrugated, each ridge being a cutting edge divided into teeth. As the bit revolves, the two cones roll around on the bottom of the well, and the great superincumbent weight of the drill stem, grief stem and swivel causes the teeth to wear away the rock. The cones can be resharpened unless too badly worn. An improvement on the original cone bit is the reaming cone bit. This has the same cones at the bottom, and, in addition, two cylindrical cutters of the same character as the cones set in the sides of the bit above the cones. These cylinnders ream the hole out to the proper gage. In drilling interstratified hard and soft formations, the cone-roller bit is the deciding factor in favor of the rotary over the percussion method.

ADVANTAGES AND DISADVANTAGES OF THE ROTARY METHOD

In drilling soft strata or unconsolidated sediments, the rotary method has several advantages over the percussion. First, there is the better maintenance of wall of the hole. There is no jarring action, as with the cable or pole-tool methods, the effect of which is to loosen the material for a considerable radius around the hole, causing serious and costly caves. Pumping mud into the hole helps consolidate the soft and crumbling walls, and, where these walls are porous, the action of the water in running off through the formation carries mud with it, rapidly sealing the walls against further percolation. This prevents loss of water, and migration of water from one well to another, with the attendant troubles and damage. The mud consistency can be varied at all times to suit the character of the material being drilled. Less casing is needed, too, because of the better walls.

When drilling in soft material with the cable-tool method, casing must be carried along close to the point of drilling to maintain the well. As casing can be driven only a comparatively short distance before it is held by friction, a new and smaller string must be set every few hundred feet, extending from the top of the well, and drilling continued with a smaller bit. In the rotary system some wells have been completed to a depth of 3,000 ft. with one string of casing, and many wells to 2,000 ft., the hole diameter throughout being maintained considerably larger than that of the casing, allowing the casing to be set with ease. This means a much lower cost per foot of well for casing, as well as a greater saving of time.

Faster time is made in soft and loose ground, because the method of cutting is more effective in this class of material; the bit is always free from cuttings, less time is consumed in setting casing, and chiefly because it is not necessary to withdraw the bit frequently and bail out the cuttings. It is claimed by advocates of the rotary method, especially manufacturers of rotary machinery, that as much as 100 ft. can be made in twenty-four hours' drilling. This is not an exaggeration. I have at hand the log of one well in which 200 ft. was made during one ten hour shift, from 100 to 300 ft. depth, in sand, shale, shell, gumbo and boulders. Another ten-hour days' work netted 120 ft. at a considerably greater depth. Where boulders are encountered in soft strata they offer no serious obstacle as a rule, because frequently they are pushed aside.

An additional advantage of the rotary system is that the driller is always informed of the exact nature of the stratum being drilled, as the cuttings are brought to the surface in a constant stream a few minutes after they are made. Thus it would be impossible for any but a slovenly driller to pass through an oil- or gas-bearing stratum without noting the fact. The cable method also is a good indicator of the strata. By the "feel" the driller can tell instantly when passing through cap-rock into a sand stratum.

In wells developing gas pressure, the hydraulic head of the mud column will often be sufficient to hold the pressure, preventing blowouts, regulating the gas flow, and permitting the drilling to be continued below this stratum. If the gas pressure is greater than the mud column will hold, a specially designed blow-out preventor can be fastened to the top of the casing, and thick mud under heavy pressure pumped in, sealing off the gas, and making it possible to resume drilling.

The rotary method gives way to the percussion process in fields where hard strata predominate, as the drilling speed attained by the rotary method is too low in such formations, and consequently the cost is too high. Also more men are required; an ordinary crew with a rotary rig consisting of a driller, three helpers, one of whom works in the derrick, and a fireman, whereas a cable-tool crew consists usually of two men, a driller and fireman. In districts having both hard rock and caving strata in quantity, a combination of the rotary and cable-tool methods is employed with great success, and will eventually be universally used under these conditions.

Important Pointers in Dyeing Silk

As a matter of importance it can be stated that there is a close resemblance of wool and silk in the general modus operandi in dyeing of silk or silk and other fibers.

The acid and basic aniline dyes are mostly used with advantage in slightly acidulated, or soap, aniline-dye solutions of about 60°C. or 140°F.

To dye silk it should first be treated, or pinked as technically called—that means the silk should be treated with tin chlorid solution of about 30 degrees Baumé and should be kept in this bath for one hour; then well washed and centrifuged and followed by another bath of sodium phosphate about 5 degrees Baumé, also kept for one hour at 167°F. and afterward well washed and centrifuged. To the tin chlorid Auerbach's extract of about 6 degrees Baumé can be added. The process of pinking silk is to give it back its natural weight and better touch and bring it back to pari.

The pari weight and touch of silk will then be approximately suitable for dyeing in acid or basic aniline dyes which have been empirically dried out by sample dyeing.

It is advisable in some cases to dye in a soap-dye solution of diluted olive slightly acidulated with acetic or sulfuric acid at a temperature of 140°F., and gradually raised to boiling of dye bath to 212°F., with a followed ariage treatment, consisting of tartaric, acetic or oil emulsions, which has the advantage of giving silk back its natural luster and shining properties. The crackling noise of silk is artificially produced by a formic acid treatment.

For example, in the bast-silk soap dye solution following aniline dyes wash well, such as:

Diamant fuchsin, rhodamine, phosphin, auramin, brilliant green, chrysoidin of the acid dyes; azo-eosin, cochineal, scharlach, eosin, saure fuchsin, waterblau, chinolin yellow—giving different shades, from a bright yellow, green, red, blue, or pink, to a brown, etc.

The dyeing of durable, wash, and light, black is a more complicated process; the aniline dyes direct will not give satisfactory results, and the old process of dyeing silk with mordants has proved fully satisfactory up to the present date. Iron nitrate, copper sulphate, and acetate, with alumina and chrom in form of chromic acid salts as mordants, have proved satisfactory with logwood extract solutions, and different tannin products such as catechu, sumac, etc.

The previous blueing process, with the yellow or red prussiate and hydrochloric acid, is also used, with the addition of small quantities of aniline blacks such as imedial black different higrosine to give a better tone in color.—Fred Klein in *Amer. Silk Jour.*

New Method of Determining Oxalic Acid

The method described by Hugo Krause, has the advantages of being very rapidly performed and requiring only simple apparatus. It can usually be carried out directly, since it is not affected by the presence of other organic or inorganic acids. The substance must be used in solid form. The method depends upon the conversion of oxalic acid into carbon monoxide, the volume of which is determined gasometrically. This reaction is well known to be brought about by the action of concentrated sulphuric acid, but it is not as generally known that acetic anhydride produces the same effect with great ease and rapidity, and quite quantitatively. When free oxalic acid is present in amount corresponding to about 0.1—0.3 grm. of oxalic acid is weighed out in a wide test-tube, fitted with inlet and outlet tubes and a small dropping funnel. Carbon dioxide is led in, and the outlet tube is connected with a Schiff's azotometer containing a 50 per cent caustic potash solution. After all the air has been expelled about 5 cc. of acetic anhydride is introduced through the funnel, and the test-tube is immersed in water at 50°—60°, which is rapidly heated until it boils gently. The volume of the carbon monoxide liberated is determined in the azotometer, and hence its weight is calculated. The method has to be modified somewhat if the oxalic acid is present as oxalate. If the oxalate is soluble in water it is simply dissolved in 15 per cent hydrochloric acid and then evaporated in the test-tube until a damp crystalline mass is obtained, which is treated as before. If insoluble oxalates are present they must be decomposed by using anhydride which contains sulphuric acid. In this last case the accuracy of the result is affected by the presence of malic acid and lactic acid.—*Ber. Deut. Chem. Gesellschaft.*

Better Concrete—I

(*Continued from page 237*)

tration of mixing water to the active material within, deferring reaction to give ease in handling. It follows, therefore, that little of this chemical action has taken place before concrete is placed in forms.

Such a protective skin is shown diagrammatically in Fig. 8, traced from an inert cement grain found in concrete as pictured in the photomicrographs Figs. 7 and 9. Obviously, control is necessary; but if quantitative reaction is sought as a means to make concrete dense and strong, with time of importance because of early thickening and hardening of such products as are casually formed, it should be advantageous to remove this dead skin in some way when ready to use cement, so that water might find access without delay and make more and stronger "glue" in the brief hour or two of freedom before setting takes place.

Of course, we must "coat" sand and stone with cement. Yet reason tells us that even an infinite supply of cement particles can cover a sand particle only so far as they may touch it at tangent points, while a solid bedment is assumed and desired in concrete. If there is not an infinite supply of cement particles, even this tangent covering is not possible.

Further, when cement particles, sand particles and pieces of stones are wet, an envelope of water covers them, preventing contact, except accidentally, even at points of tangency, as shown in the diagram Fig. 8, traced from the photomicrograph Fig. 9. This explains why there is rarely, if ever, contact between particles as their relative positions are revealed in magnified photographs.

COMPOSITION OF AGGREGATE

A little thought and calculation with regard to aggregates reveal certain other facts not often considered. Briefly, these are that in a cubic yard of 1:2:4 concrete, there are about one million stone particles, up to and including 1½ inches, that there are about twenty-five billion sand particles with a commercial coarse sand, or two hundred billion particles with a very fine sand, all of which have to be distributed and wetted and mixed with some two hundred to three hundred billion cement particles in space of time that will pay commercially—usually less than a minute. Evidently, since this is so, "covering" sand and stone with powdered cement would really mean that when using fine sands, not to exceed 1 to 1½ cement particles for each piece, large or small. Covering should be actual and thorough and uniform, but obviously true covering can only come through spreading of a liquid cementing product; and to achieve even a fair result there must be no "unstirred sugar" left, else some billions of potential workers will be rendered idle through denial of means wherewith to do their appointed share of work. Remembering these things, further light may be gained by reconstructing the processes that formed a representative concrete, now in existence.

PHOTOGRAPHIC STUDIES

Concrete from a warehouse at Lynn, Mass., is shown in Fig. 7, magnified 60 diameters. In it are clearly visible the sectioned sand grains with their irregular outlines; the clear matrix of hydrated cement; a few voids, and some "unstirred sugars" in the forms of unhydrated cement particles. Fig. 9 is an enlargement to 180 diameters of the section limited by lines in Fig. 7. It is to be remembered that in each of these photographs the relative positions held by the several substances are the positions held by them when placed in forms and that must be held by them so long as the concrete endures.

What happened when this relationship was first established? All cement particles in the vicinity doubtless reacted with water rather quickly for some time after the protecting skin was pierced. During this interval the sand grains lay surrounded by water, waiting quietly whatever might happen, save, perhaps, for an occasional settlement to easier position as concrete deposited above increased the general pressure.

At the surface of cement particles, however, there was at first saturation of the hydrated skin; then spasmodic reactions as water first reached active cement, formed new products ,became seated and gradually diffused, then renewed activity as new water reached deeper layers of active cement through the same agencies, with repetition of the processes until setting of the richest products directly at the surfaces of the cement particles formed a new protective skin and brought about a shut-down of hydration.

The water-filled space about cement and sand particles was, during this time, gradually becoming charged by diffusion with these cementing products. But diffusion is slow; and as distance from the source increased, concentration of these products became less, being least at the surface of the sand particles, where for man's purposes it should have been greatest. If diffusion could have been aided by stirring, this defect would have been overcome; and, furthermore, longer activity of the cement particle would have been possible through removal of those surcharged products at its surface (where richness was not desired) and supplying of fresh water. Surely, one way of improving concrete should lie in procuring by some means a greater concentration of cementing products and distributing these instead of insulating and diluting water over the sand and stone before they find their final position in forms. If this were done, "water voids"—spaces left by water uncharged with cementing products—would disappear, for there would then be no uncharged water, and the nature of such charging products is to solidify. With this accomplished, there should be evident an increase both of strength and of specific gravity.

(To be continued)

The Langmuir Postulates—II

(*Concluded from page 247*)

Corresponding salts of HN_3 and HCNO are isosteric, and the data in the literature, as far as they go, show that their solubilities are the same.

KN_3 and KCNO are both tetragonal; their ratios of axes are below:

KN_3	1 :0.5798
KCNO	1 :0.5766

Both give strong negative double refraction, and both have (001) and (111) as their most common crystal faces.

Let us conclude the list with mentioning a couple of salts that never were supposed to show any twinlike qualities: $No.+ NO_3-$ and $Co++ CO_3--$ which are almost identical in crystalline form, optical properties and cleavage. This is now accounted for by the fact that the NO_3- and CO_3-- ions are isosteric. Since the force holding the $Ca++$ and CO_3-- ions together is four times as great as that holding $Na+$ to $NO-$, it is more difficult to separate the ions, from which we understand why $CaCO_3$ is but slightly soluble, whereas in $NaNO_3$ the ions are easily separated in such a dielectric solvent as water, and that when the ions are separated, $NaNO_3$ becomes an electrolytic conductor.

XI

The theory, as may be observed, opens up vast possibilities. We can imagine periods of perplexity and dizziness after we have tried with sticks and balls of wax to build up atoms and molecules in the almost infinite number of chemical possibilities and we almost dread the task. It is usually difficult to present things of three dimensions in drawings of two, and the Langmuir atoms and molecules and compounds are all of three dimensions. We may have been somewhat negligent of this concept rather than ignorant of it in our methods heretofore. Whether this generation will take its chemistry in cubical atoms and build up its molecules and compounds in block-houses according to these postulates rests in the lap of the future for determination, but we think them too full of promise to be neglected for years as was Willard Gibbs' phase rule. We regard the work as a contribution of the first moment to the science of chemistry. And we believe that, as they are developed and revised and applied in practic, they will become familiar and easy of comprehension. We subjoin a revised list of the postulates prepared for a forthcoming article on the subject by the author of the system.

XII

THE LANGMUIR POSTULATES

I—The electrons in atoms are either stationary, or rotate, revolve, or oscillate about definite positions in the atom. The electrons in the most stable atoms, namely, those of the inert gases, have positions symmetrical with respect to a plane passing through the nucleus at the center of the atom. No electrons lie in the equatorial plane. There is an axis of symmetry (polar axis) perpendicular to the equatorial plane through which four secondary planes of symmetry pass, forming angles of 45 deg. with one another. These atoms thus have the symmetry of a tetragonal crystal.

II—The electrons in any given atom are distributed through a series of concentric (nearly) spherical shells, all of equal thickness. Thus the mean radii of the shells form a narithmetric series, 1, 2, 3, 4 and the effective areas are in the ratios 1; 2^2; 3^2; 4^2.

III—Each shell is divided into cellular spaces or cells, occupying equal areas in their respective shells, and distributed over the surface of the shells, according to the symmetry required by Postulate I. The first shell thus contains 2 cells, the second 8; the third, 18, and the fourth 32.

IV—Each of the cells in the first shell can contain only one electron, but each other cell can contain either one or two. All the inner shells must have their full quotas of electrons before the outer shells can contain any. No cell in the outside layer can contain two electrons until all the other cells in this layer contain at least one.

V—When the number of electrons in the outside layer is small these electrons arrange themselves over the underlying ones, being acted on by magnetic attractive forces. But as the charge on the kernel or the number of electrons in the outside layer increases, the electrostatic repulsion of the underlying electrons becomes predominant, and the outer electrons then tend to rearrange themselves so as to be as far as possible from the underlying one.

VI—The most stable arrangement of electrons is that of the pair in the helium atom. A stable pair may also be held by: (a) a single nucleus; (b) two hydrogen nuclei; (c) a hydrogen nucleus and the kernel of another atom; (d) two atomic kernels (very rare).

VII—The next most stable arrangement of atoms is the octet, that is, a group of electrons like that in the second shell of the neon atom. Any atom with the atomic number less than 18 and which has more than three electrons in its outside layer tends to take up enough electrons to complete its octet.

VIII—Two octets may hold one, two or sometimes three pairs of electrons in common. One octet may share one, two, three or four pairs of its electrons with one, two, three or four other octets. One or more pairs of electrons in an octet may be shared by the corresponding number of hydrogen nuclei. No electron can be shared by more than two octs.

Heterodyning Wavemeter.

(*Concluded from page 241*)

wave-meter as far away from the transmitting station as possible, as otherwise misleading results may be obtained.

In addition to acting as a receiving wave-meter, it may also be used as a transmitter without any alteration to its circuits, since the valve is oscillating and therefore radiating feeble waves. If, therefore, it is desired to adjust a receiving circuit to a given wavelength, all that is necessary is to adjust the wavemeter to the required wave-length and to tune the set to it. The device is also of great use as an external heterodyning oscillator for use with a non-oscillating detector for the reception of continuous waves.

These devices were presented to the Inventions andDepartment of the Ministry of Munitions early in 1917, and modifications have been described by the author in the *Wireless World*.

Spectral Structure of the X-Rays

Barkla and Miss White have recently announced the discovery of the existence of a new series of X-rays, obtained by the absorption method with the lightest elements (C, O, and Al) and coming immediately above the K-rays in the scale of frequencies. It is interesting to study their spectral nature, which is possibly simpler than that of the K series, which comprise four monochromatic radiations. The only element which has the smallest atomic number (N=5), and at the same time has physical properties which enable it to be used as anticathode, is boron, and moreover by extrapolation from the results of Barkla its J-rays should fall in the absorption band of silver, so that the study of its rays by the photographic method is specially indicated. The authors have performed this investigation and find that the continuous spectra are very regular, the K discontinuities of bromide and silver being very clear. No ray of wave-length in the neighborhood of $\lambda=0'43$A.U. nor even contained in the interval $1\cdot0<\lambda>0'2$A.U. could be detected, which is a remarkable fact for an element of atomic weight lower than those of the gases of the air. If the J-rays of boron are emitted with an appreciable intensity in proportion to the continuous spectrum they constitute a single ray which coincides with the K discontinuity of silver. —*Comptes Rendus.*

A sample plot established before the appearance of the chestnut blight to determine yield and rate of growth. Now of great value in marketing dead and dying trees.

A stand of pure chestnut full of promise before the advent of the chestnut blight. Now it is doomed to die. It will yield 30,000 shingles to the acre.

Use the Dead and Dying Chestnut

Importance of Immediately Salvaging Wood of Trees Killed by Fungus Growth

By Prof. Joseph S. Illick, Chief of Bureau of Silviculture, Penn. Dept. of Forestry

During the past decade the chestnut blight, which was imported from China, has caused enormous damage in the forests of the eastern United States. The disease has spread over almost the entire range of the native chestnut, and in many regions where this species once prevailed and formed dense stands of promising timber, only a few scattered and subnormal specimens now remain. There are only a small number of isolated and remote areas within the extensive range of this once important timber tree into which the destructive parasitic disease has not yet migrated. It has already done an enormous amount of irreparable damage, and unfortunately no satisfactory preventive measure of control has yet been found. This lamentable condition exists in spite of the fact that the life history of the disease is now thoroughly understood.

Satisfactory preventive measures may be developed at a later date, but until hopes in this direction are realized, all immediate effort should be directed toward salvaging the useful wood contained in the millions of dead and dying trees now standing upon thousands of acres of mountain land and farmer's woodlots.

Owners of timberland are beginning to realize that the advance of this fungous foe cannot be stopped, and that inestimable loss will follow in its wake, unless the destroyed trees are marketed immediately. Immediate utilization is imperative for the wood of the killed trees deteriorates rapidly under the subsequent attack of rots, insects and other destructive agencies. It is therefore recommendable to market not only the dead and dying chestnut trees, but also the few living trees which remain, for they, too, will soon fall victim to the fatal disease.

While it is recommendable from a forestal point of view to cut all chestnut trees of merchantable size, there is an economic question to this procedure which cannot be ignored, namely, whether the products derived from so wholesale a cutting of such a widely distributed forest tree in so short a period of time can be disposed of at a profit to the landowner and the forest operator. The larger trees may be manufactured into dimension stock, boards, piles, and telegraph and telephone poles for which there exists a rather heavy and constant demand. But only a small percentage of the material which must be immediately salvaged occurs in the larger sized trees, the greater percentage being found in relatively small trees, so characteristic of the second growth forests. These small trees are difficult to market on account of their small size and superabundance. A considerable quantity, however, is being sold for posts, ties, and fuelwood; and in the manufacture of extract, staves, and shingles an additional large quantity is now being used annually. The amount consumed for the foregoing purposes may be considerably increased by collecting and disseminating reliable and practical information concerning satisfactory marketing methods, and yield possibilities per acre and per tree of the commodities which are now manufactured from small-sized chestnut trees. In accordance with this point of view data will be presented herewith concerning the present status and possibilities of the chestnut shingle business.

Felling a dying chestnut tree for shingles.

Sectioning the trunk into shingle bolts.

The annual output of chestnut shingles at the time of the last census was running close to 100,000,000, and present conditions promise a marked improvement of the market, for chestnut heads the list of all the shingle woods of the country in value per thousand. One of the most essential qualities of a good shingle is durability and this desirable quality the chestnut possesses in good measure, for sawed chestnut shingles under favorable conditions will last 25 years, and if shaved they will endure for 40 years

No phase of the business is obscured in darkness to a greater degree than the possible yield of shingles per acre, per tree, or per unit of volume. And until the land owners and mill operators are enlightened upon this subject, they cannot talk business with one another, nor plan their work along economic lines. It appeared urgent, therefore, that an investigation be undertaken to determine the possible yield of shingles from small and medium-sized trees. This was done in 1917 under the direction of the writer on the Mont Alto State Forest in Pennsylvania. In order to procure reliable field data, a large number of trees were selected, felled, and followed from the forest through the mill to the finished product. As soon as a tree was felled it was given a number, which was marked upon the basal section by an imported marking hammer. Each section or shingle bolt cut from a tree was marked with the number of the tree, and in addition bore a number which indicated its position among the sections. This dual system of marking facilitated the reassembling of the sections at the mill and eliminated the possibility of error.

The primary results of the study are shown in the accompanying chart and the subjoined tabulation:

Diameter Breast-High (inches)	Volume Including Bark (cubic feet)	Number of of 4"x21" Shingles Per Tree	Number of Shingles Per Cubic Foot of Volume
7	5.00	75	15.0
7.5	6.20	110	17.7
8.0	7.70	155	20.1
8.5	9.75	205	21.0
9.0	11.22	255	22.7
9.5	13.18	305	23.1
10.0	15.00	355	23.7
10.5	17.26	415	24.0
11.0	19.75	475	24.1
11.5	21.90	555	25.3
12.0	24.20	635	26.3
12.5	26.75	710	26.5
13.0	29.60	785	26.5
13.5	32.50	865	26.6
14.0	35.40	930	26.3
14.5	38.10	995	26.1
15.0	40.60	1,050	25.8

The foregoing tabulation contains some striking and helpful results. A tree with a breast-high diameter of 7.5 inches contains 6.2 cubic feet and will yield 110 shingles, while a tree with a breast-high diameter of 15.0 inches, that is, twice the diameter of the former tree, contains 40.6 cubic feet and will yield 1,050 shingles. This shows that a tree with a breast-high diameter of 15 inches will yield almost ten times as many shingles as a tree with a breast-high diameter of only 7.5 inches. Furthermore, the tabulation shows that the optimum-sized tree for shingle production has a breast-high diameter ranging from 11 to 14 inches, for trees of this size yield from 24 to 26.5 shingles per cubic foot of volume, while trees ranging in size from 7 to 8.5 inches yield 15 to 21 shingles per cubic foot.

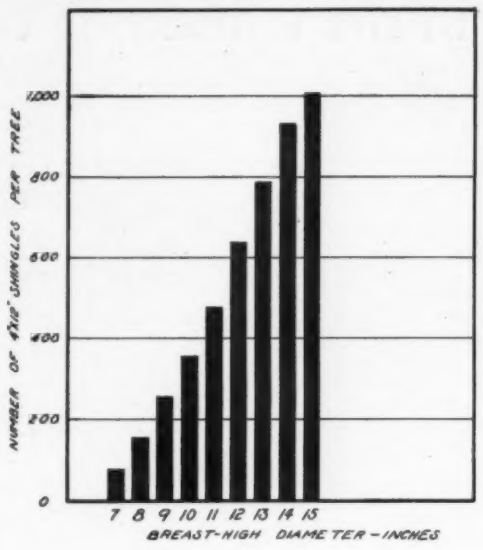
The relatively low yield of shingles obtainable from small trees is due to their poor form and the proportionately larger amount of bark which covers them. The bark on the stems of small merchantable trees is approximately as thick as that found on medium-sized trees. Therefore, their bark comprises a much larger percentage of the total volume than that of larger trees. The percentage of the total volume of chestnut trees comprised by the bark is given in the following table:

Breast-High Diameter (inches)	Percentage of Bark
7	26.5%
8	22.1
9	21.5
10	20.0
11	19.5
12	18.1
13	17.3
14	16.7
15	15.7

The number of shingles obtainable from various-sized ranks is also of great practical value to the woodland owner and timber merchant. A rank of bolts 8 feet long, 4 feet high, will yield 1,255 standard shingles, providing the bolts average approximately 12 inches in diameter. A standard cord (8x4x4 feet) will yield approximately 3,750 shingles (4x16 inches).

The percentage of waste in the process of manufacturing shingles is a subject which deserves some consideration. Of the total volume of medium-sized trees (including branchwood) only 46.4 per cent remains in the shingles, and in case of small trees only 38.3 per cent is left in the finished product; that is, 53.6 and 61.7 per cent respectively is wasted in the process of manufacture. This wastage may appear high, but it is not much higher than that of the ordinary portable sawmill operation. Fortunately, all the waste of a shingle mill may be used in firing the boiler, which supplies the power to operate the mill, and thus the total wood loss is considerably reduced.

The cubical volume of each tree and the shingles derived therefrom were determined by the use of a special instrumnt, technically known as a xylometer, the operation of which implies the displacement of a volume of water equivalent to the volume of wood. This was accomplished by immersing the wood in a tank filled with water, and then measuring the volume of overflow water. The entire operation of the instrument is simple, and the derived results far more accurate than can possibly be attained by the most careful and accurate calculation of volume from linear measurements.



Yield of Chestnut Shingles.

The results of this study, which pertains primarily to the yield of chestnut shingles, may enable the owners of timberland stocked with chestnut to estimate more accurately the volume and value thereof, and thus make it possible for them to dispose of it profitably to some local shingle mill operator. For example, an owner of timberland has a tract of land situated some distance from his place of residence. It is stocked with chestnut, most of which is dead or dying due to the attack of the chestnut blight. The owner is anxious to dispose of his timber, but has no idea of its value on the stump nor the yield in terms of some marketable commodity. A survey is made of the tract and it is ascertained that the area which should be cut over aggregates 100 acres and that the average acre bears 150 chestnut trees with an average diameter of 11.5 inches. Supplied with the foregoing information, which is readily collected, the owner can determine the value of his timber in terms of shingles by using the accompanying table on shingle yield. This table shows that a tree with a breast-high diameter of 11.5 inches will yield 555 standard 4" x 21" shingles. Therefore, the average acre with 150 trees will yield 555 X 150, or 83,250 shingles, and from the entire tract of 100 acres may be procured 8,325,000 shingles. If shingles sell at a price of $9 per thousand and the cost of manufacture is $6 per thousand, then allowing 50 cents per thousand profit to the mill operator, there remains a stumpage value of $2.50 per thousand. On this basis there would be a stumpage value of over $200 per acre.

The previous example assumes a rather heavily stocked stand and a diameter somewhat higher than that which prevails in most chestnut stands. Consequently, the stumpage value of an average acre of chestnut timber would be less, especially if located at a considerable distance from the market.

A yield of 20,000 shingles per acre is possible from thousands of acres stocked with blighted chestnut. This represents a stumpage value of $50 per acre, and requires only 80 trees with an average breast-high diameter of 9 inches. It follows, therefore, than it might be profitable to the woodland owner to consult with a mill operator pertaining to the conversion of his chestnut wood into shingles, and thus probably bring a profit to himself and the mill operator. For, if the mill operator makes only a profit of 50 cents per thousand he will net $5 per day with a mill having a daily capacity of 10,000 shingles.

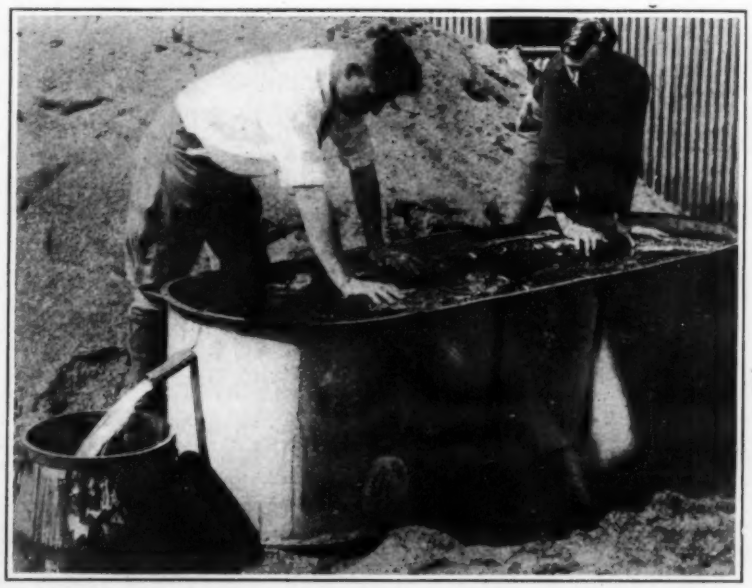
Briquetting Alabama Graphite

Alabama graphite is sold in the form of thin, flat cakes which pass through a 20-mesh sieve. It has been suggested that if these flakes could be converted into larger granules the product would be improved for use in crucible manufacture and would more closely resemble Ceylon graphite.

Samples of Alabama graphite were mixed with tar and briquetted at different pressures ranging from 500 to 5,000 lbs. per sq. in.; these were coked rapidly at 1,000° C., crushed, and screened between 16- and 100-mesh sieves. As anticipated, the most desirable properties (highest crushing strength, lowest porosity, highest density, and lowest bulkiness) were found when high pressure (5,000 lbs. per sq. in.) were used in briquetting. It was found that 15 per cent. of tar gave the best results, except for the lowest pressure, when up to 20 per cent. of tar is required. A large sample (200 lbs.) was made by mixing 3 parts of Alabama flake of 20-mesh and 1 part of 100-mesh graphite dust, adding 15 per cent. of tar, compressing into briquettes under a pressure of 5,000 lbs. per sq. in., coking at 1,000° C., and crushing and screening the product between 16- and 100-mesh sieves.

Crucibles containing raw Alabama graphite were moulded with difficulty; the graphite is "slippery," causing the material to adhere to the tool and slide rather than pack against the mould. It did not weld readily and laminated badly. The coked product perfectly and showed no welding seams or laminations. Contrary to expectation, however, four crucibles containing raw Alabama flake graphite gave better service than (1) four others containing coked graphite and (2) four crucibles containing Ceylon graphite. The results require confirmation on a larger scale.—Abstracted by *The Technical Review* from *Journal American Ceramic Society.*

Reassembling sections of individual chestnut trees to determine yield of shingles per tree.



A practical xlymeter—an instrument for accurate determination of cubical contents of tree's shingle bolts and shingles.

Problems in the Utilization of Fuels—II*

Economic Use of the Poorer Grades of Coal and Oils

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Considerable preliminary investigation is accordingly essential. The particular object of such investigational work should be to ascertain the conditions for, as well as to determine the plant modifications necessary in, obtaining the maximum production of the best grade of crude oil in the retorts which are selected for development. The profits resulting from the sale of the products of an additional stripping plant, namely, gasoline and fuel oil, would probably make such pioneer research work actually self-sustaining. Including the necessary condensers and tankage, and laboratory and shops, an experimental unit retorting plant having a throughput of, say, 100 tons per day should not entail the expenditure of over $50,000. Its erection should immediately follow the demonstration of the continuity and uniformity of the seams through a desirable area; and it should not be enlarged to, say, a plant of 1,000 tons daily capacity until after the successful conclusion of extensive study.

Quite a number of processes have been proposed for the production of crude oil from American shales, but, up until December 1, 1918, none of the several Western companies was producing. A number of patents have been issued, but it is doubtful whether many of them possess any commercial importance; in fact, it is questionable whether any improvement or additions to previous knowledge are presented which would withstand legal consideration. To quote from a recent report: "In the attempt to reduce the modest amount of labor required by the successful Scottish retorts, many mechanical monstrosities have been evolved whose operation would require a gang of mechanics and a heap of repair parts. Others exhibit the utmost ignorance not alone of distillation methods, but of furnace design and the principles of combustion and chemistry. It would seem that some company organized primarily to get shale-oil would be well advised to erect Scottish retorts and adapt them to local conditions. These well-tried furnaces are mechanically good—they operate on recovered gas with a minimum of labor, make a good yield of satisfactory crude oil with an increasing amount of paraffin, and permit the recovery of large amounts of ammonium sulphate. Should labor-saving devices be considered essential, the modern by-product coke-oven with its marvelous mechanical equipment could be taken as a model, and so modified as to produce the regular temperature cycle needed for maximum yield."

The contention is not made in this paper that any type of Scottish dual-purpose retort[7] should constitute the actual basis for the development of an American shale-oil industry, for this retort is not the design which is required today to handle most economically all grades of oil-shale; but it is essential that more careful consideration be given to Scottish experience in retorting practice. This successful experience and the misfortune of those who attempted to establish shale-oil industries in Australia and New Zealand have demonstrated that the retort and its operation must be adapted to the specific shale to be retorted, and always with due regard to local industrial, financial, commercial and meteorologic conditions. The dual-purpose retort was a failure when used in Australia because it was totally unsuited for dealing with the richly kerogenous, yet non-nitrogenous, shale of New South Wales; whereas the oil-shales of Scotland are generally low in yield of oil and relatively high in yield of ammonia, when destructively distilled in the same type of retort. It is therefore unsurprising that a large amount of money was lost in this attempt to obviate experimental work by adopting a retort which was very successful on a totally different variety of oil-shale under entirely dissimilar economic conditions. American oil-shales are comparatively high in characteristic kerogens,[8] but in the Western States they are generally low in nitrogen-content, while in New Brunswick, for instance, the oil-shale is highly nitrogenous, although it yields an oil inferior to the Scottish. In fact, almost every condition to be encountered on this continent differs materially from the conditions which have been responsible for the Scottish dual-purpose retort.[9]

A Henderson retort, one of the Scottish types, has been erected by the Southern Pacific Railroad at Elko, Nevada, and, with adequate financial support and technical supervision, this attempt to adapt Broxburn practice to an American deposit should result in the accumulation of valuable information. It may be noted here that two small modified Henderson retorts were erected near DeBeque over a year ago by another organization. One of these retorts was operated for a short time, upon its completion, while the other was given more recent trials, but not much crude oil was produced in either attempt. It is doubtful if more than 20 barrels of crude shale-oil were produced up to January 1, 1919, from western oil-shale. Much of the oil-shale agitation is unfortunately company publicity and it is clear that proper development is impossible as long as the stock promoter remains the prominent feature of the situation. The successful exploitation of our oil-shale reserves will require careful investigation on the part of a competent technical and sales staff. For the assurance of successful large-scale operation, a retorting process must be used which will give good yields of economically refinable crude-oil and, wherever commercially possible, of ammonia; easy methods must be perfected to separate the unstable compounds from the products of the crude-oil, and the market must be educated to absorb the finished products of the refinery.

SOME SPECIFIC ENGINEERING PROBLEMS IN THE UTILIZATION OF FUELS.

From an industrial engineering standpoint, the problems arising in connection with fuels and their use are various indeed. The operating engineer is, however, chiefly concerned with the many difficulties encountered in securing perfect combustion; the proportioning of boiler heating surfaces, combustion spaces, and grate areas; flue-gas baffling within the boiler for utilizing the maximum amount of heat; and clinkering.

Examining the entire subject of the utilization of fuels in its varied engineering aspects, it is found that the conditions of firing present an array of frequently encountered problems. In the case of coal, there are found: the type of stoker as influenced by the character of the fuel; the provision of draft; the control of flue gas; flame properties; crushing and sizing; reduction of flue-gas temperatures; air leakages through settings; radiation on conduction of heat through settings; design of combustion space for perfect burning; furnace refractories; clinkering and ash disposal, and storage.

While engineers have generally agreed as to the draft requirements and grate areas for various kinds of fuel, no definite data are available regarding the furnace volumes required and the rates of combustion for various types of fuel. How can we most economically ensure proper and complete combustion of coal on boiler grates and elimination of losses due to improper firing? How can we minimize heat losses due to scale, flue dust and improper boiler settings? A practical method of heating material with less unused space in furnaces is cent was lost through radiation and conduction and also an appropriate subject for research. The determination of reasonable specifications for Kentucky, Tennessee and other coals and cokes requires consideration. What is the best method of burning efficiently low-grade coals which clinker badly? What is the most suitable method of burning high sulphur coal without clinker or fusion? Research attention should be accorded the development of a satisfactory furnace-lining for high-sulphur fuels. How can peat and lignite best be used in rotary furnaces, such as dryers and kilns? What is the most efficient type of automatic grate for burning screenings or slack coal? Successful automatic stokers are wanted for burning low-grade anthracite fuel. Inquiry has also been made for a relatively inexpensive, simple, mechanical stoker which would be suitable for installation under process furnaces where the consumption of coal is limited. And, then, what is the most satisfactory means for burning coal and wood refuse in combination?

In modern designs of steam-boilers it is not possible to convert over 13 per cent. of the total heat value of the coal into steam power. This condition has been long discussed, and designs of stoking machinery, smoke consumers and other devices intended to obviate this great loss are numerous. To find the remedy for this loss of fuel, it appears to be in line that before we can successfully construct apparatus to handle fuel and obtain the greatest evolution of heat, it is first essential to standardize a raw fuel by concentrating it into a fuel of homogenous structure. This may be accomplished by coking and briquetting processes, each of which has its special advantages. The manufacture of artificial fuels or briquets is a field in which great advancement can be made, for it enables a number of low-grade fuels to be mixed with those of greater density and consolidated into a fuel which may be moved without breakage and at a minimum transportation cost. Fuel briquetting in America has not met with the success up to this time which it rightfully deserves, although, of course, certain of the difficulties have grown out of the inexperience of the operators as well as the fact that a number of the plants have not had adequate financial support. Of over 50 installations which have been made in the United States, only 10 are now in operation. Recent work on the briquetting of Clinchfield coal is of interest here. One process is to remove first a small amount of the volatile matter from a tar-bound briquette and then to harden by further heating.

The development work done in combustion through the use of stokers, in combination with under-grate blowers and retorts, has about exhausted the possibilities in this direction, and a radical departure from the existing practice is necessary in order to utilize to the fullest possible extent the thermal energy of fuel. The use of fuel in pulverized form offers a basis for further development work in this connection.

With pulverized coal, we have the problem of crushing and drying, explosibility and storage, injection into the fire-box, and refractory erosion. In particular, the most economical method of storing and handling pulverized coal with boilers requires more exhaustive investigation. And what over-all boiler efficiencies are obtaned in burning pulverized coal? Easily cleaned regenerators for furnaces using pulverized coal are desired. And, finally, what is the relative value on a heat and cost basis of pulverized coal, fuel oil and producer gas?

Scientific smoke inspection, together with improved furnaces and fireplaces, has done and will do much to abate the much discussed smoke nuisance, but smoke will never be finally abolished so long as raw bituminous coal in its present form is used as a fuel. While the use of mechanical stokers will assist along this line, the hope of eventually effecting the abolition of the evil lies principally in three general directions. The first is a wider extension of the use of gaseous and powdered fuels for heating purposes, and researches having for their purpose the increment of the efficiency of gaseous combustion, or the improvement of the use of pulverized coal and the generation and application of gas for fuel purposes, are enacting contributory roles of importance. The second is the adoption, along very broad lines, of electricity as a motive power. The third lies in the trend of manufacturing some form of semi-carbonized coal as a smokeless domestic fuel at a price which will not exceed that of raw coal, and this problem is now receiving serious investigation, especially in Canada and England.

*Reprinted from the *Journal* of the Society of Chemical Industry, June 30, 1919.

[7]Simpson (Chem. Met. Eng., 20 (1919), 204, employs this term to illustrate the fundamental object of Scottish practice, viz., the production of crude oil and ammonia in one retort.

[8]On American oil-shales, see Baskerville and Hamor, J. Ind. *Eng. Chem.*, *1* (1909), 507; Orig. Com. Eighth Internat. Cong. Appl. Chem., *25*, 631; Ells and Hamor, *loc. cit.*; and Bull. U. S. Geol. Surv., Nos. 581-A and 641-F.

[9]On the principal factors involved in Scottish shale-oil technology, see Bacon and Hamor, *lib. cit.*, *2*, 807 *et seq.*

In case of gas fuels, there are the important problems of the improvement of burners and methods of air-mixing. In producer-gas technology, not much trouble is reported with mechanical-type producers; but with the fixed-type, clinkering, incomplete burning of coal, air-holes and pressure have been causes of complaint. What is the most economical size and shape of producers for gas to be used for heating purposes? The economic utilization of the tar by-product from producers requires more study; and engineers request research on the automatic, separate control of the steam and air blasts in producers, and a practical automatic check and regulation to maintain the uniform quality of producer gas. A large steel company has been investigating the problem of making a washed by-product gas luminous on burning. But perhaps the greatest need in gaseous fuels is obtaining a cheap fuel gas from a central station large enough to conduct profitable by-product recovery, and this problem is now receiving attention by two American companies.

With fuel oil, there are the problems of explosibility, storage, burning for perfect combustion, and action on furnace refractories. Insufficient and improperly adapted oil-burners have caused expensive difficulties in burning oil. Some trouble is still experienced in burning heavy asphalt-base fuel oil; and burners clog occasionally, even with light fuel oils. Localized heat renders the use of fuel oil less desirable than washed producer-gas, according to some engineers. The combustion of fuel oil to secure good heat regulation where different temperatures are required at various stages of the operation of chemical apparatus, and the use of fuel oil instead of coal for steaming and open-evaporating, with relative costs, are problems of chemical industry. There are also inquiries regarding a widely applicable method of utilizing waste heat from oil and gas-fired apparatus, more efficient oil and gas burners, and a simple and efficient combination gas and oil burner.

The most potent factors in the conservation of fuel during the last twenty years have been: (1) the development of water power, (2) the concentration of the production of power from fuel in central stations where the most economical methods may be utilized, and (3) the distribution of power electrically. There is still much to be done in the way of replacing inefficient isolated power plants of various kinds and sizes with electric power. From the point of view of fuel conservation the most important field remaining for the most extended use of electricity is on the railways. One-fourth of all the coal mined in the country, as well as a considerable quantity of oil, is consumed by steam locomotives. The locomotive is an isolated power plant of but medium efficiency, and the only excuse for its continued existence is the cost of electrification.

FUEL PROBLEMS IN THE REFRACTORIES INDUSTRY.

The fuel difficulties encountered in the burning of refractories divide themselves into two classes, one of which deals with the efficient use of the heat units developed and the other relates to the securing of heat.

When heat balances are made of kilns they show that from 8 to 12 per cent. of the heat is used to develop the ware, i.e., to expel moisture, complete the chemical reactions which may take place, and thoroughly shrink the refractory article. From 40 to 75 per cent. of the heat is lost to the kiln itself, in heating it and by radiation. From 10 to 25 per cent. of the heat is carried out by the hot stack gases. These difficulties are largely overcome by the use of continuous kilns, whereby the fuel requirement is decreased from 1,950 pounds to 700 or 750 pounds per thousand brick. There are three problems of this general nature, viz.:

(1.) Decreasing radiation loss;
(2.) Decreasing stack losses; and
(3.) Decreasing kiln loss.

However, the most important problems pertain to the development of the heat.

(1.) The heat must not be too intense at any one point or some ware will be burned unnecessarily well and other ware will require to be reburned.

(2.) There is the problem of conveying producer gas from a central plant to the various kilns without losing a great amount of heat, i.e., by the cooling of the gas.

(3.) The pulverized fuel problems consist in the prevention of the deposition of ash-dust and in developing a feeder which will work slowly at low temperature and yet give combustion. This feeder must be a unit in itself, since, because of the fact that the kilns are round, one cannot have a central shaft as a source of power.

(4.) A fourth problem is that of securing good draft at all times. When the air is "muggy," the temperature increase is very slow and often the kiln cannot be properly finished. By using "artificial draft," secured by fans, it may be overcome.

(5.) In the fire-boxes the tendency is to clinker. At the lower temperatures these boxes must be "cleaned" after about the fourth day. The full heat is then applied and the boxes must be cleaned every 6 to 12 hours, depending upon the fuel. Every time they are cleaned the fire practically goes out, cold air rushes in and the kilns fall from 50 deg. to 200 deg. in temperature. This problem resolves itself into the provision of suitable draft as well as fuel, but is caused mostly by the clinkering of the coal used.

(6.) A minor problem arises from the tendency of the ashes to fall on the brick and remain on them. This troublesome deposition may spoil 500 to 2,000 bricks in a kiln. As a rule, old bricks are put in these ash-collecting positions, and are used over and over again.

FUEL PROBLEMS IN THE GLASS INDUSTRY.

In the glass industry the problems related to fuels may be divided into two groups, viz., economic and engineering problems.

Economic Problems.—The first requirement for the glass factory is that the supply of fuel shall be continuous. This is obvious since the fire is maintained in the furnaces for eleven and sometimes for eighteen to twenty-four months. The fact that an interruption of the supply of fuel may necessitate a virtual rebuilding of the furnace illustrates the need for a continuous supply of fuel. The second requirement is a fuel of low cost. The cost of fuel averages approximately the same as the cost of the raw materials of which the glass is made and comprises about 10 per cent. of the total manufacturing cost of the glass.

Natural gas has fulfilled both of these requirements to an admirable degree; but since the price has risen above $0.20 per 1,000 cubic feet, and especially since the supply is becoming inadequate and intermittent in certain localities, the glass industry is facing the economic problem of a new source of fuel. Fuel oil is being used as an emergency fuel, but it is too expensive for general use. Coal is therefore considered, from the economic standpoint, as the most suitable source of fuel since it satisfies both of the conditions noted above. It should be mentioned, however, that experiments are in progress on the use of electrical energy for melting glass, as well as for heating the annealing leers and kilns. The possibility of utilizing electricity in glass-making opens up a large field, with many problems both of an engineering and economic nature.

Engineering Problems.—The application of oil as a fuel involves practically the same engineering considerations as that of gaseous fuels. Mechanically and thermally it is an entirely satisfactory fuel. Coal is sometimes burned directly in the pot type of furnace, but this is inefficient and is not the usual practice. It is not applicable for tank furnaces, and the transformation of coal into producer gas is therefore the most general and efficient manner of using coal in the glass industry. Improvements in the design of producers and the application of the lower grades of coal offer opportunities for the betterment of the glass industry. Powdered coal has been in experiment for melting glass, but has not been successful because of the ash and other impurities which contaminate the glass and choke up the flues. A successful elimination of these factors would go far towards fuel economy in glass making. Powdered coal is, perhaps, applicable to pot furnaces and to the newer type of muffle annealing leers and kilns, but some form of gaseous fuel would be necessary for the "glory holes," the "fire polishing" flame, and the small "cracking off" and melting flames employed in finishing certain kinds of glassware.

One of the most important problems in the glass industry is that of heat economy. Glass furnaces are notoriously wasteful of fuel. Accurate measurements of the heat balance of glass furnaces are few, but it has been shown in the case of a plate-glass furnace that of the total heat supplied only 17 per cent was required to melt the glass, while 56 per cent was lost through radiation and conduction and in the chimney gases. Even in some of the modern tank furnaces the loss of heat is deliberately increased by air blasts against the outer walls of the furnace.

The application of the fuel to the furnace is crude in the sense that the present practice is to a large extent the result of empirical methods. Scientific research in the standardization of furnaces; in the determination of the most efficient number, size and position of the ports, in the arrangement of the baffles, in regulating the air supply and the gas pressure, and in the most efficient construction of the regenerators, will, without question, effect marked economies in the amount of fuel required in the glass industry. The furnaces used for melting glass in closed pots are far less efficient, thermally, than tank furnaces. Owing to the arrangement of the pots (they rest upon a solid brick hearth and are placed close together and close to the furnace wall), the heat for melting the glass must be conducted or radiated through only the top and back walls of the pot. A furnace designed to heat the pots evenly on all sides would greatly reduce the heat loss in this thermally inefficient type of furnace. There is need for a more uniformly heated leer and for more accurate regulation of leer temperatures. Such control would result in more uniform annealing and less subsequent breakage, and would in many cases eliminate the necessity for a second annealing in the kiln. The same remarks might apply to the annealing and decorating kilns, which could probably be replaced by a really efficient continuous leer.

Thus, the problems of fuel in the glass industry are also closely related to those of refractories, of furnace design, and of pyrometry; and improvements in the materials and the design of the furnace and of the scientific methods of control will materially assist in reducing the amount of fuel at present wasted.

FUEL PROBLEMS IN THE IRON AND STEEL INDUSTRY.

The economic manufacture of iron and steel is dependent, not only upon the raw materials available, but also on the judicious combination of their utilization and the recovery of all by-products. It is probable that the greatest fundamental error has been made by considering fuels in their relation to metallurgy alone and by not regarding them in a two-fold aspect rather than a single one. To illustrate: In the smelting of iron we have first the coke-oven, which yields not only the metallurgical fuel, but also a gas which is extremely useful for domestic purposes, and then, too, ammonia is produced. In the utilization of the so-called waste gases of the blast-furnace there is presented a fuel which is available for the production of energy on an enormous scale, and this energy must, in many cases, be sold to outside parties if it is to be used. Because of collateral matters of this nature, it is necessary, in the treatment of fuel problems arising in the iron and steel industry, to take a comprehensive view.

Everything is concentrated that goes into the furnace (ore, coke, fluxes, etc.), except the oxygen of the air, which is added with four times its volume of inert nitrogen. If more concentrated air or even pure oxygen could be used, a great saving could be effected, and there could be done in combustion furnaces much which is now only possible in electric furnaces. This problem has been frequently discussed, but comparatively little research has been devoted to it.

The problem of sulphur is one of the most important in iron metallurgy. Sulphur is one of the most deleterious elements which can be present in iron, and, while it can be kept out, notwithstanding the high affinity of iron for it, the procedure is expensive. When charcoal is used as a blast-furnace fuel, only about four-fifths as much of it is required to make a ton of iron as when coke is burned, although the fixed carbon in charcoal is equivalent to but 75 per cent of that contained in coke. The same considerations are applicable in the conversion of iron into steel. To keep the sulphur content to a minimum is increasingly difficult, as the amount of sulphur in the fuel becomes higher. The ash problem is next in importance. The disadvantages which arise from ash are very great because of the increasing slag volume and the difficult character of the slags frequently produced.

Another series of serious problems in iron metallurgy relates to the closely allied by-product coke industry. An important problem is the reduction in cost of plant. The large amount of capital invested for

even a small sized by-product coke-oven plant is such as to deter many who would otherwise be willing to install by-product coke-ovens. There is no doubt that much can be done toward decreasing this cost by simplifying the means of operation and possibly by the use of less expensive materials of construction. There are also possibilities in the way of improving the heating of the coke-ovens. Much has already been accomplished in this direction, for it is only a few years ago that by-product coke-ovens were making practically no surplus gas, whereas records from recently constructed plants show as much as 62 per cent. surplus gas. The importance of any scheme for further reducing the amount of fuel required for coking the coal depends, of course, upon the value of the heat units saved in any particular locality. The value of the heat units required to coke one ton of coal in existing plants is about $0.30, so that the possibilities of further saving are limited to fractions of this amount. Another problem relates to the improvement of the refractory materials used in by-product coke-oven construction. Much has been accomplished by the substitution of silica brick for the old fire-brick, and if there were available a succedaneum for silica brick that would make a proportional improvement, the advantages to the industry would be very great. Possibilities have also been considered in the way of making the cooking process a continuous operation, and, finally, there is a great field for improvement in the recovery and utilization of the by-products.

One of the greatest needs of all industrial life is particularly required in the manufacture of steel. Reference is had to some method of gas production which will enable the gasification of coal with high efficiency and with the product possessing a calorific value of not less than 500 B.t.u. per cubic foot.

It has been maintained that tar-oil can advantageously replace coal in many instances for the heating of open-hearth and other furnaces in which a regular temperature and neutral atmosphere are required. Certainly this replacement requires the consideration of research. The question of the recovery of the whole of the gas from coke-ovens is a problem which is encountered by all builders in new installations. If ordinary producer gas is employed for heating the coke-ovens, and advantage is taken of double regenerators to heat up both this gas and the air supply, it is claimed that all the gas from the ovens will be recovered. The application of approved types of producers adapted to low-grade fuel is another problem; it is contended by some engineers that these should be used exclusively, and, of course, in large installations the recovery of the by-products from the producers can be taken into account.

Is Alcohol Dead?

(*Concluded from page 243*)

strenuous efforts to get a substitute, possibly postponing this important task until hardship results.

The lack of a successful small still might also be urged as further reason for the failure to use alcohol industrially. Many have pointed to Germany with a naive wave of the hand and exclaimed that the matter of a small still is merely a matter of wanting it. The Department of Agriculture thinks differently and admits that up to the present, one has not been secured. The German experience has been that notwithstanding the extra rebate given the small distiller and the associations formed to give him a boost, he has difficulty in making it pay. He has one great trouble in the very short season of operation, as unlike the large distiller, he cannot command raw materials from a distance. He only uses the materials on his own farm. Dr. Harvey W. Wiley, who has investigated the problem considerably, thinks that the small still cannot come here, for with prohibition at hand, it would require an army of revenue officers to cover our vast area to keep alcohol from getting into the throats of the topers.

Some allege that wood alcohol and benzine (not benzene) denaturents are not pushed as they might be, were they in the hands of those who desired to sell them in great quantities. The prices may seem unreasonably high and the production may be curtailed. However, since benzine sold last year at about forty-five cents a gallon, such price does not appear prohibitive. Wood alcohol was over a dollar a gallon at the same time, but this was unusual. It is thought that if enough of the denaturents cannot be secured, Congress can be prevailed upon to increase them, albeit Congress is a slow-moving body.

In conclusion, it might be said that the need of a new fuel in the future is evident because of the rapid decline of the old petroleum fields and because of the greatly increasing demand for fuel resulting from the large number of gas engines. The requisites of a motor fuel, namely, mechanical efficiency, cheapness and abundance, were applied to the other leading substitutes and then to alcohol. It was found that with proper adjustments alcohol would be a more efficient fuel than gasoline. The variety and abundance of our products indicates that they could be easily manufactured here or in the tropics. That alcohol has not been prominent is accounted for by the quantity and price of petroleum, by the absence of a small still and possibly by the lack of plentiful and cheap denaturents. When alcohol will come as a fuel cannot be accurately predicted, but that it will come is confidently expected by engineer and economist alike.

Alcohol is not dead. It is to be regretted, however, that in raising the makings of alcohol, man will have to toil hard at a back-breaking job rather than as now, tap a well and have millions of gallons of valuable fuel burst forth from the earth to be gathered and sold for gold by its discoverers.

Catalytic Dehydrogenation by Nickel in Presence of Hydrogen

The hydrogenation of benzene hydrocarbons over nickel at a temperature of about 180° gives the corresponding cycloformic hydrocarbons. Thus, pinene yields the dihydride without any accessory reactions. But if the temperature is raised a different reaction occurs. If pinene and hydrogen are led over a column of liquid at about 350°-360° a liquid is obtained which is hardly affected by sulphuric acid, but is energetically attacked by a sulpho-nitric mixture. This liquid consists of a mixture of benzene hydrocarbons (cumene and cymene) and a saturated hydrocarbon not attacked by the sulpho-nitric mixture. The density and absence of rotatory power indicate that it is a menthane and not pinene. Thus, hydrogenation and dehydrogenation occur simultaneously, but the presence of hydrogen is indispensable in order that the reaction may take place—without hydrogen a mixture of terpenes is obtained, arising from the isomerisation of pinene by heat, which is facilitated by the presence of nickel. Other compounds besides pinene undergo the same changes. Thus, limonene gives a little saturated hydrocarbon, but nearly all the product is a mixture of cymene and cumene. Camphene gives analogous results, and menthene reverts respectively to cymene and benzine. The same reaction has also been applied to oxygen compounds, and cyclohexanol, for example, has provided a regular yield of phenol. This method of dehydrogenation in presence of nickel can advantageously be applied to the production of benzols from terebenthene, while the hydrogenation at lower temperatures (about 180-200°) gives only cyclones and formic hydrocarbons. —*Comptes Rendus.*

On Whole Numbers for Atomic Weights, and Related Questions

The question has again come forward in modern physics as to whether the observation data for a definite group of magnitudes (*e. g.*, for the atomic weights of the elements) relate to a series of integral multiples of a unit, and only diverge from these owing to experimental errors. In the case of the first 24 elements of the periodic system not less than 20 differ at the most by 0.1 from the next whole number, and it appears reasonable to assume a strong bias towards the integer hypothesis. In other cases, *e. g.*, the Langevin-Weiss theory of magnetons, for whose admissibility the verdict as to the integral character of the series of numbers appears to be actually decisive (See Abs. 1586 1912) ,the need for an objective criterion occurs. Hitherto for the treatment of this problem, the sole means employed has been the Gauss theory of errors. R. von Mises demonstrates the inadequate character of this method, and develops a cyclic theory of errors to replace the linear theory of Gauss, which admits of a more comprehensive solution being obtained. He claims to have found a definite criterion for integral character —namely, an expression which, from the observation data, gives the probability that the true values are integers. Section 1 states the problem to be solved. Section 2 derives the cyclic law of errors. Section 3 deals with measurements of precision, etc. Section 4 evolves the integer criterion. Section 5 gives applications of the theory. A short appendix deals with the calculation of the cyclic error integral. The example specially studied is that of atomic weights, and an application of the theory to modern electrical questions is promised for the near future.—*Science Abstracts.*

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